



Element-based mapping to identify industrial symbiosis opportunities in the UK cement, steel, glass and ceramics sectors

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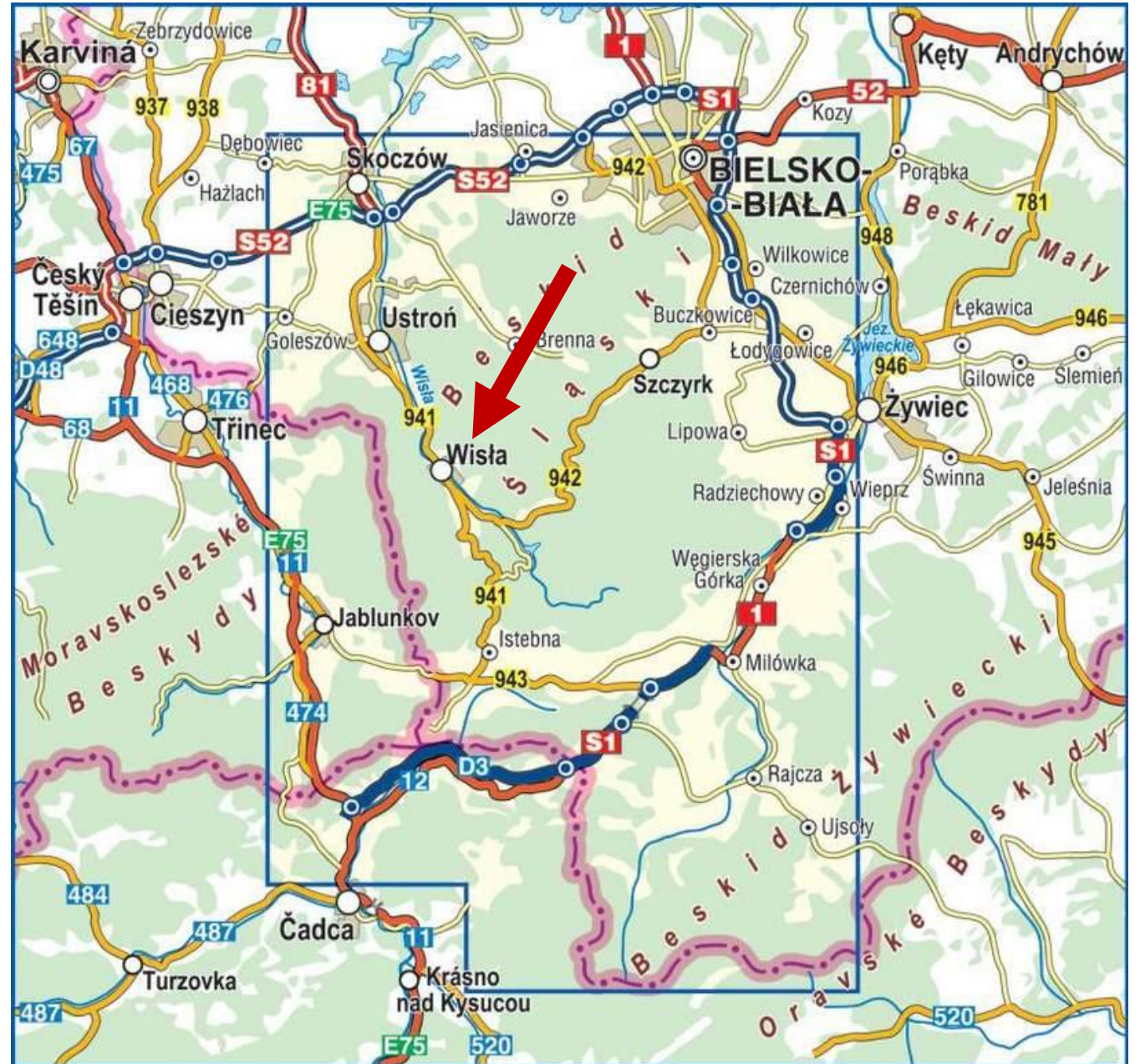
School of Civil Engineering, University of Leeds
Construction Materials Laboratory, EPFL

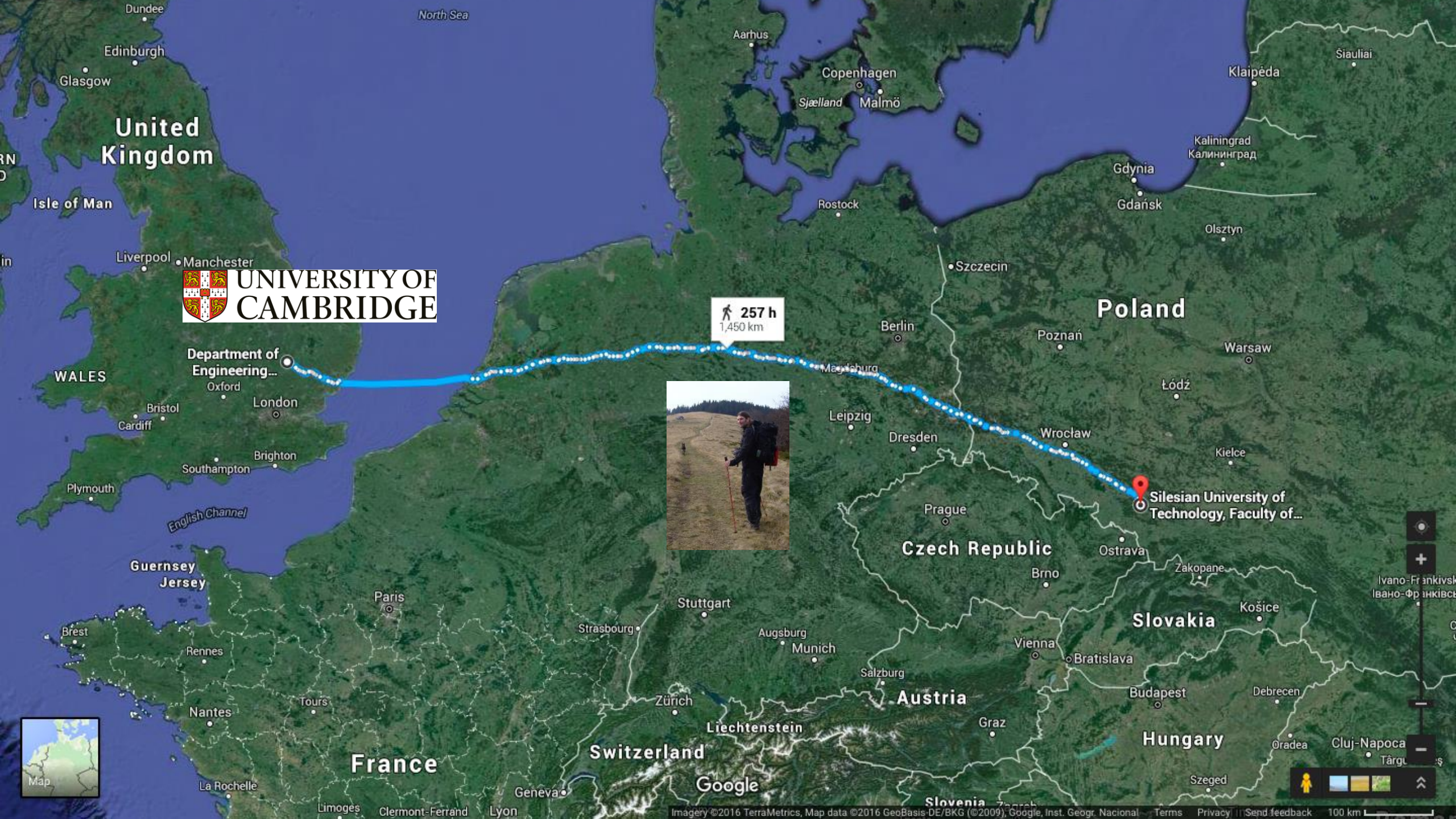
TFIN+ Christmas Conference
5-6 December 2023



A map is a symbolic depiction emphasizing relationships between elements of some space, such as objects, regions, or themes.

...





United Kingdom


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Department of Engineering...

 257 h
1,450 km

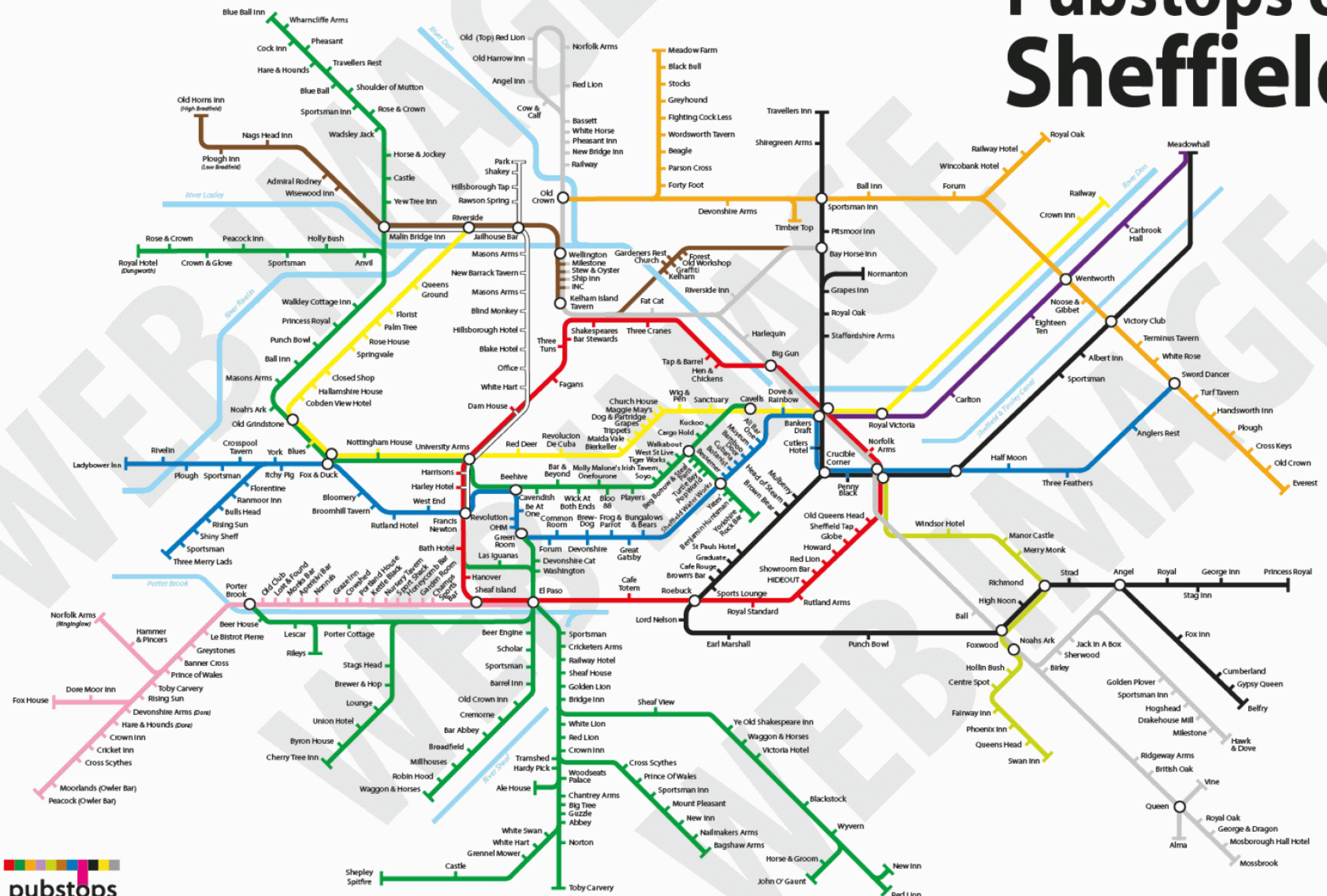


Poland

 Silesian University of Technology, Faculty of...

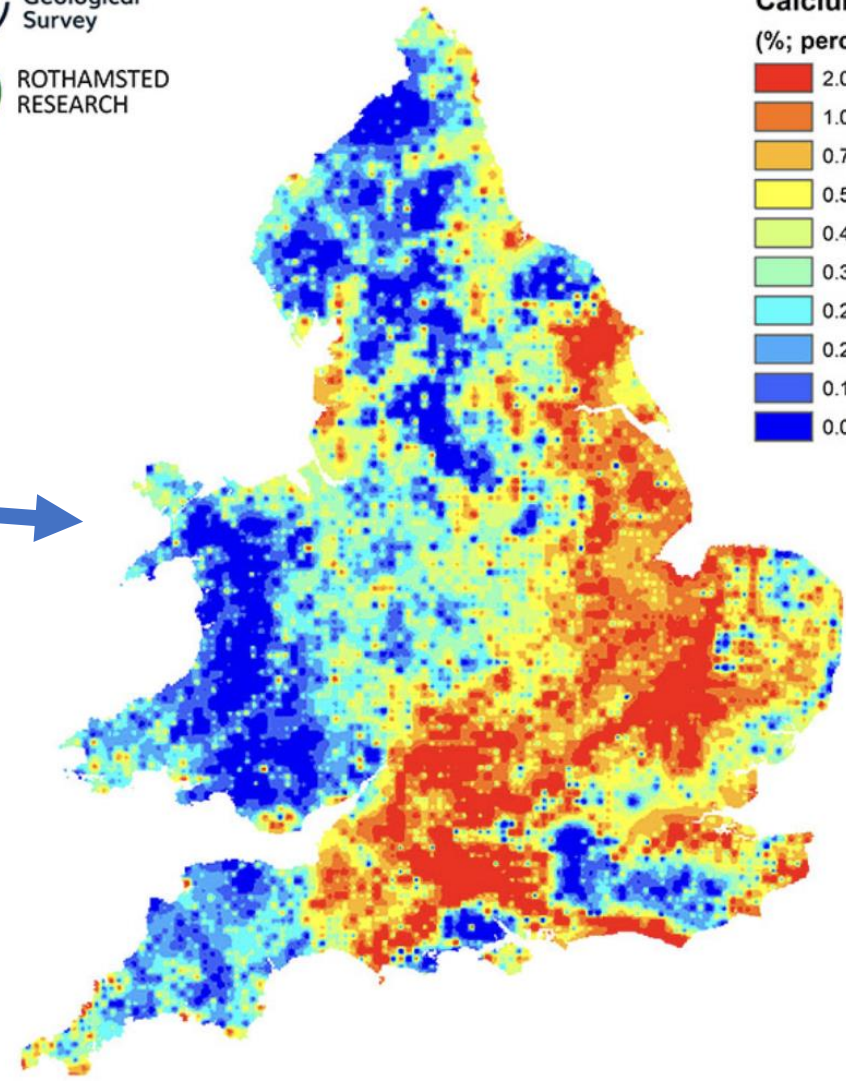
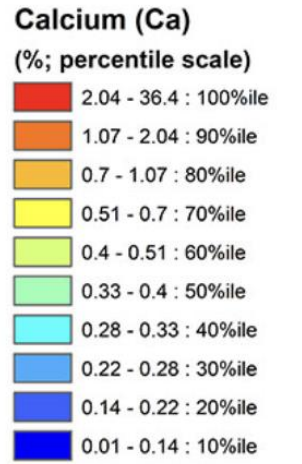
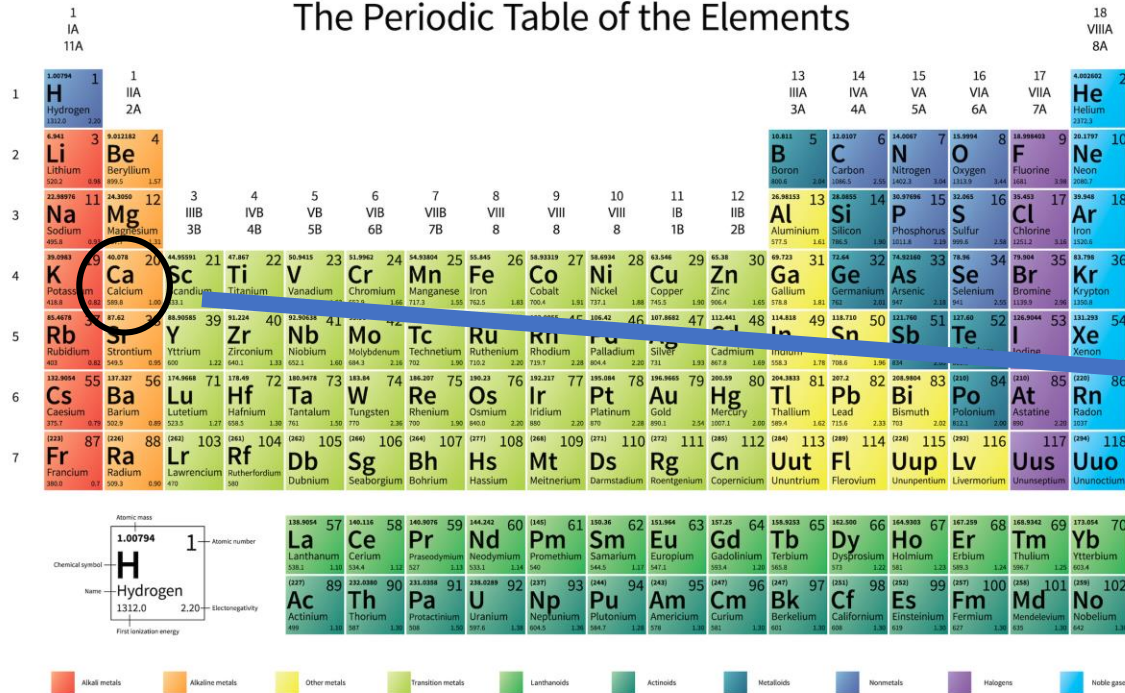


Pubstops of Sheffield



Source: www.pubstops.co.uk

The Periodic Table of the Elements



Foundation Industries



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Foundation Industries



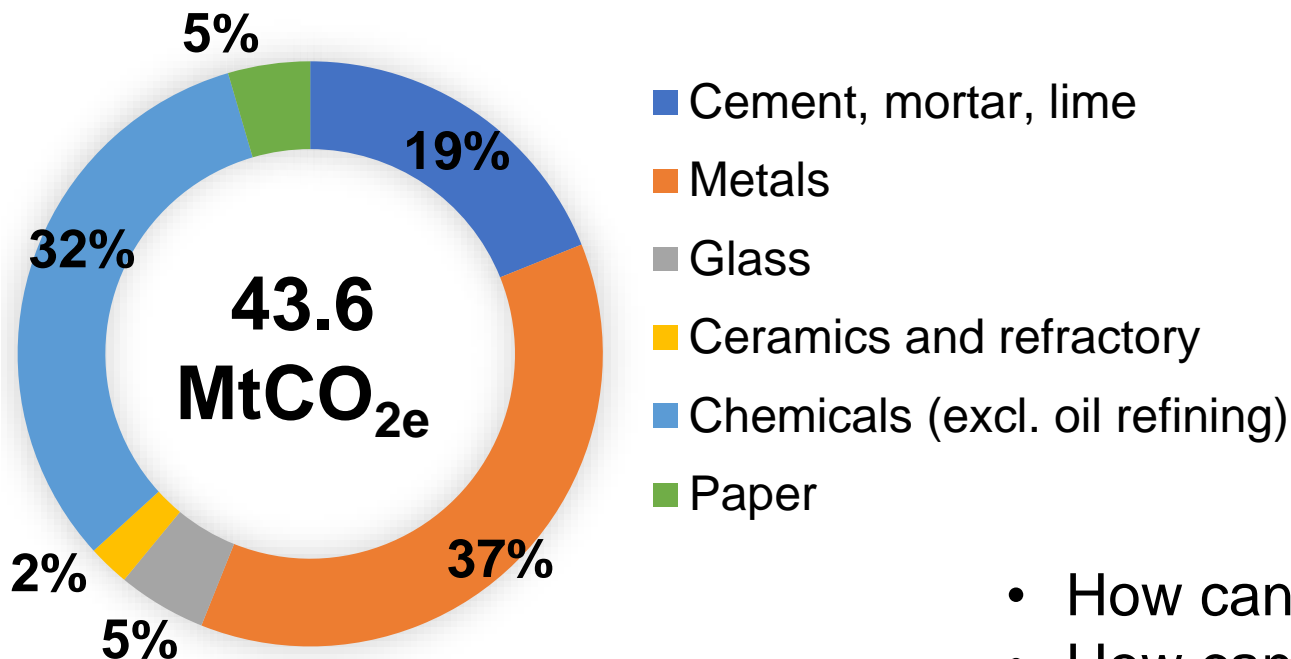
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12-13 Mt waste per year (DEFRA, 2022)

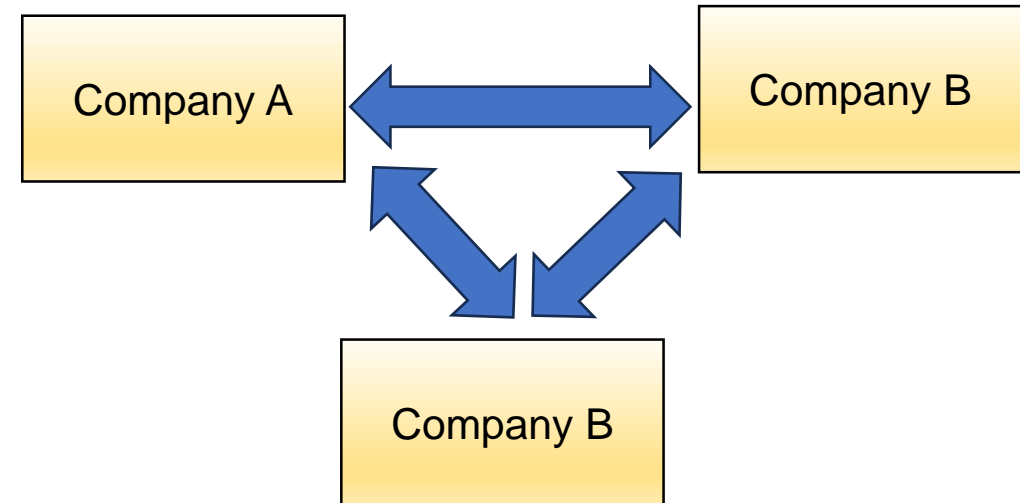
43.6 Mt CO_{2e}

>250,00 people with turnover of >£67 billion

(ERC, 2021)



Industrial symbiosis is part of the **UK decarbonisation strategy** (UK Government, 2021)



- How can we best **decarbonise**?
- How can we **reduce waste flows**?
- How can we **generate income** from by-products?

Availability of information is a known barrier to **industrial symbiosis** (Golev et al., 2015).

Existing matching approaches are valuable, but have limitations (**names of waste, EWC codes, common sense**).

To identify unexplored **material stream** industrial symbiosis opportunities - can we be more...

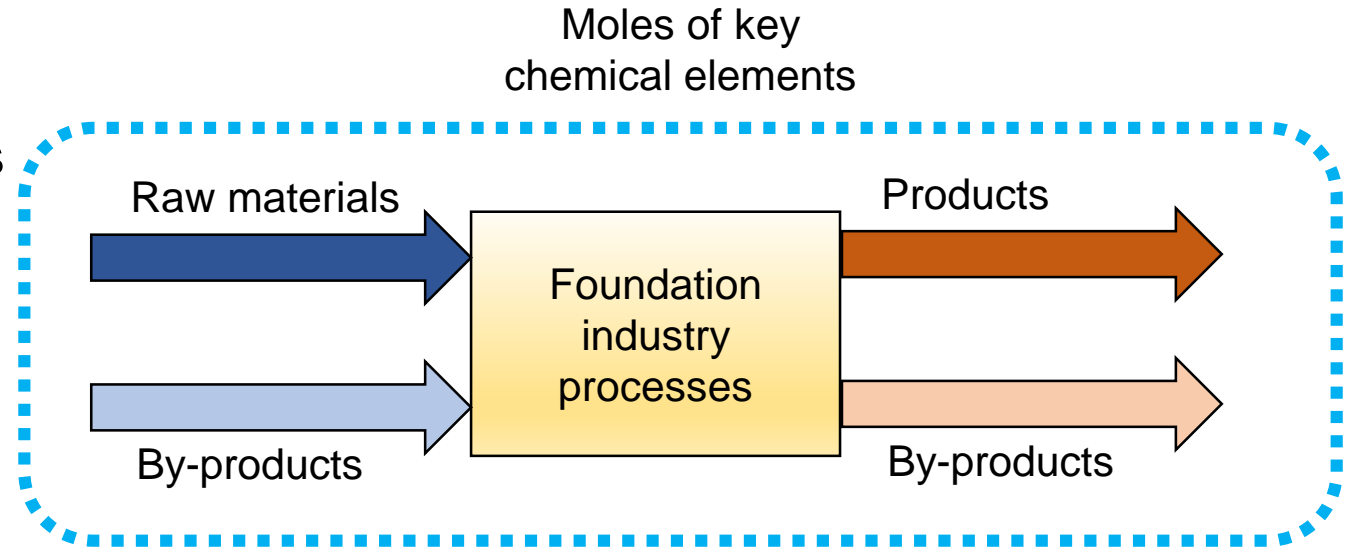
- Visually intuitive?
- Future-proofed?
- Data-driven?

Draw on perspectives from other sectors, e.g. rare earths (Du and Graedel, 2013), pharmaceuticals (Wołos et al. 2022).

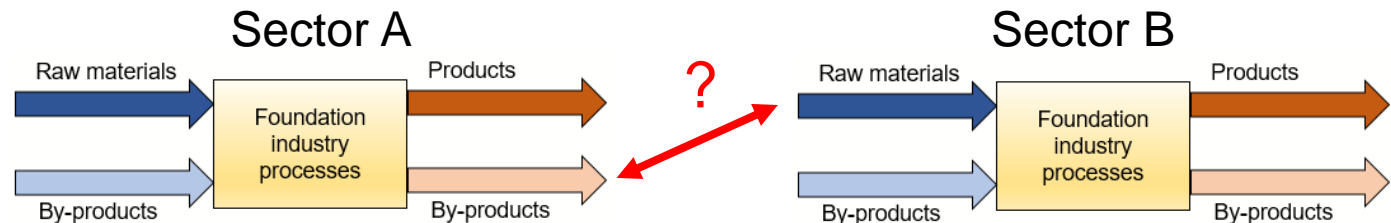
Approach



1. Map input and output **material flows** using **chemical elements**
2. Report in units of **moles** (i.e. # of atoms)
3. Focus on a **small number** of key elements



ADVANTAGES	DRAWBACKS
<ul style="list-style-type: none">+ Very simple+ Intuitive to make links+ Fundamental units	<ul style="list-style-type: none">- Very simple- Neglects minor elements- Non-intuitive units- Dependent on data availability



Scope of study and research approach



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Question:

Can an **element-based mapping visualisation approach** be used to help identify **previously unexplored industrial symbiosis opportunities** between foundation industries in the UK?

Can we identify matches **between sectors**?

Sector scope

- Cement
- Glass
- Ceramics
- Steel

Research approach

- Desk-based modelling
- Workshops with 4x industrial partners

Input data

- From literature
- From industrial partners



E.g. brick clay



Oxide	Al ₂ O ₃	CaO	K ₂ O	MgO	SiO ₂
wt.%	17.1	3.4	2.8	2.0	57.5

Chemical oxide composition
(wt.%)

Annual material flow
(tonnes)

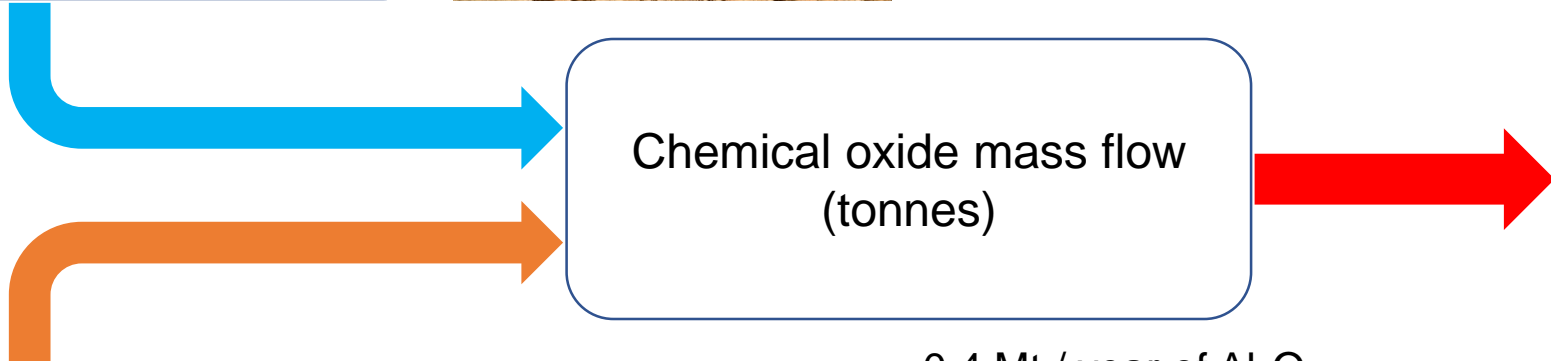
~2.5 Mt / year of
brick clay

Chemical oxide mass flow
(tonnes)

0.4 Mt / year of Al₂O₃
1.4 Mt / year of SiO₂
(in brick clay)

Elemental flow
(moles)

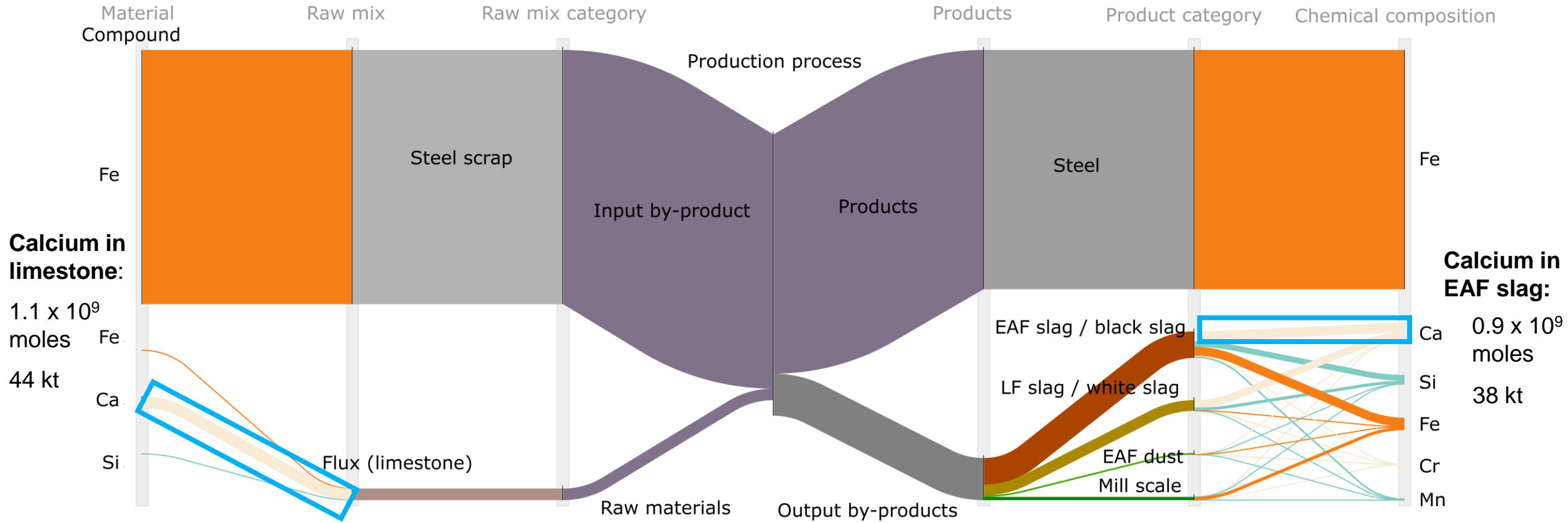
8.4 x 10⁹ moles of Al
2.4 x 10¹⁰ moles of Si
(in brick clay)

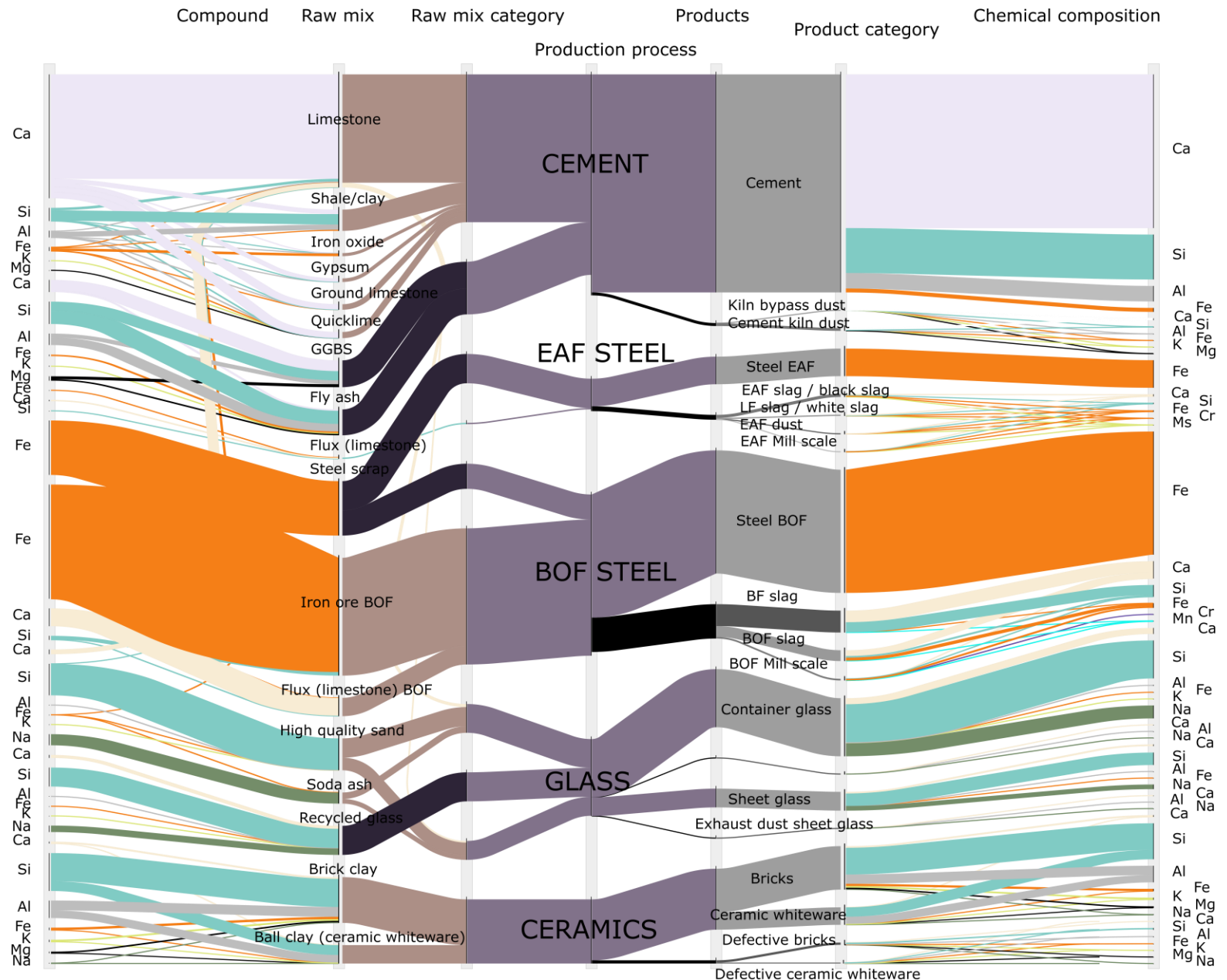


Visualisation



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Ca
Si
Al
Fe
K
Mg
Ca
Si
Al
Fe
K
Mg
Ca
Si
Fe
Fe
Ca
Si
Fe
Ca
Si
Fe
Ca
Si
Fe
Ca
Si
Al
Fe
K
Na
Ca
Si
Al
Fe
K
Na
Ca
Si
Al
Fe
K
Mg
Na

Ca
Si
Al
Fe
K
Mg
Fe
Ca
Si
Cr
Fe
Ca
Si
Fe
Mn
Cr
Ca
Si
Al
Fe
K
Na
Ca
Na
Ca
Si
Al
Na
Ca
Na
Si
Al
Fe
Ca
Na
Si
Al
Fe
K
Mg
Na

Limestone
Shale/clay
Iron oxide
Gypsum
Ground limestone
Quicklime
GGBS
Fly ash
Flux (limestone)
Steel scrap
Iron ore BOF
Flux (limestone) BOF
High quality sand
Soda ash
Recycled glass
Brick clay
Ball clay (ceramic whiteware)

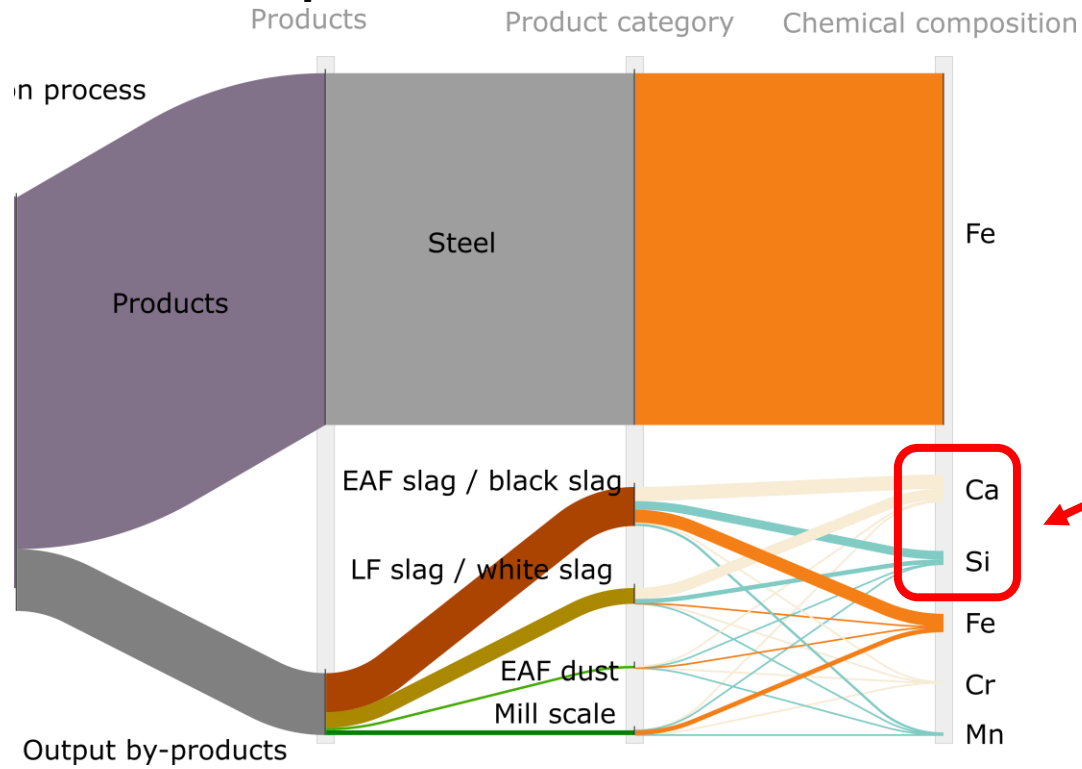
CEMENT
EAF STEEL
BOF STEEL
GLASS
CERAMICS

Cement
Kiln bypass dust
Cement kiln dust
Steel EAF
EAF slag / black slag
LF slag / white slag
EAF dust
EAF Mill scale
Steel BOF
BF slag
BOF slag
BOF Mill scale
Container glass
Sheet glass
Exhaust dust sheet glass
Bricks
Ceramic whiteware
Defective bricks
Defective ceramic whiteware

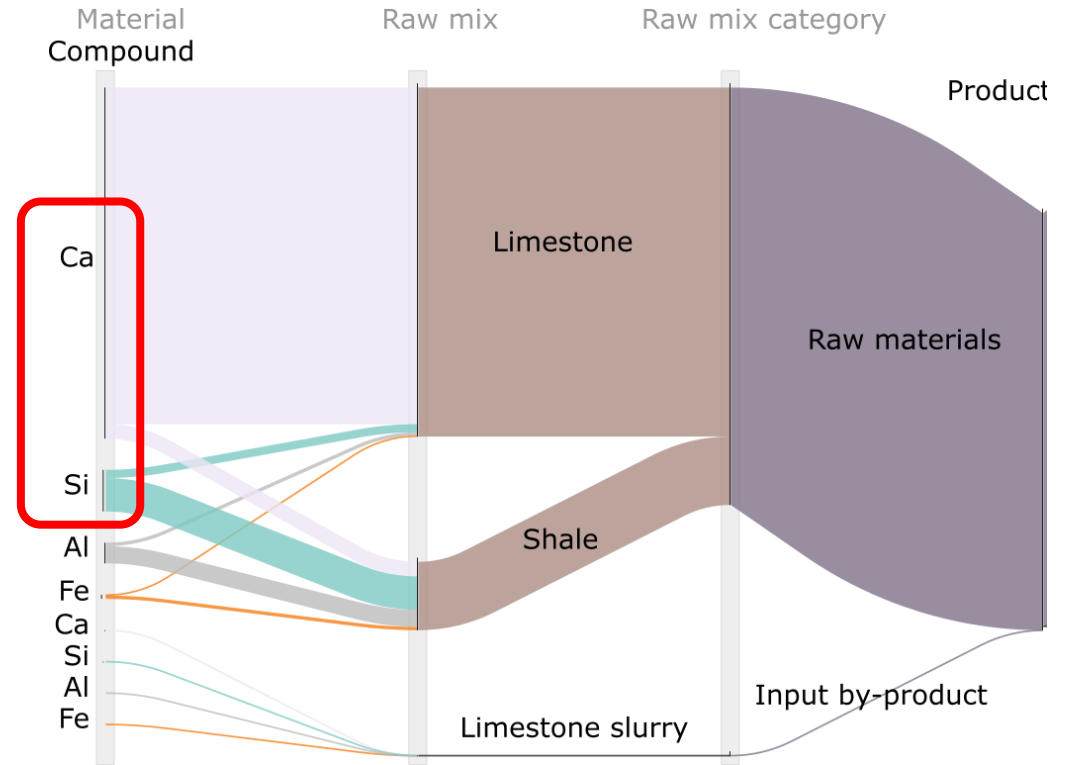
Visualisation



EAF steel **output** material flows:



Cement (clinker) **input** material flows:



Shortlisted matches



1. Longlisting



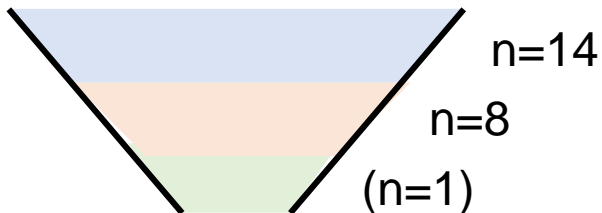
2. Shortlisting



3. Detailed evaluation

- Identify which inputs and outputs have **similar elemental composition**

→ Generate longlist of matches



Go through **longlist** of matches, and identify:

- Are matches already in practice? If not...



- Have matches already been tried? If not...



- Match goes through to shortlist.

→ Generate shortlist of matches

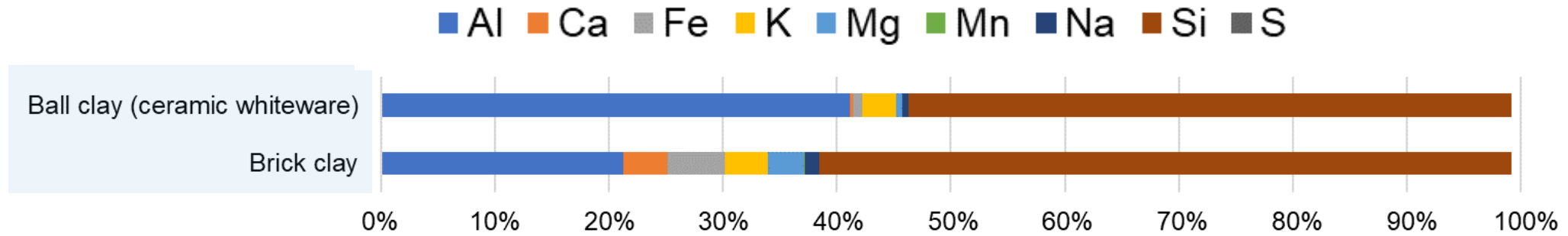
Evaluate potential of **shortlisted** matches, on the basis of:

- Quantities
- Physical form
- Minor element requirements
- Other material requirements

→ Identify matches to develop feasibility studies for

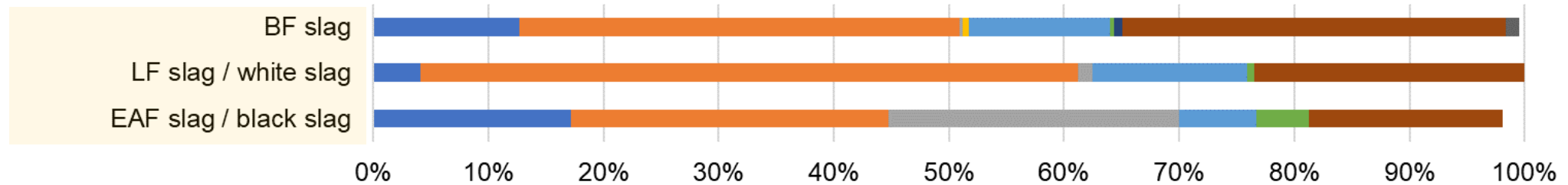
Shortlisted matches

Candidate raw materials inputs (ceramics)



Which by-products from other sectors have similar composition?

Candidate by-product outputs (steel)



Shortlisted matches



		Input raw materials			
		Ceramics	Glass	Steel	Cement
Output by-products	Ceramics		X	X	X
	Glass	X		X	X
	Steel	Blast furnace slag, electric arc furnace slag and ladle furnace slag as potential replacements for brick clay	X		Ladle furnace slag as a potential replacement for shale/clay
	Cement	X	Cement kiln dust and cement kiln bypass dust as potential replacements for limestone	Cement kiln dust and cement kiln bypass dust as potential replacements for limestone	

Potential for future use



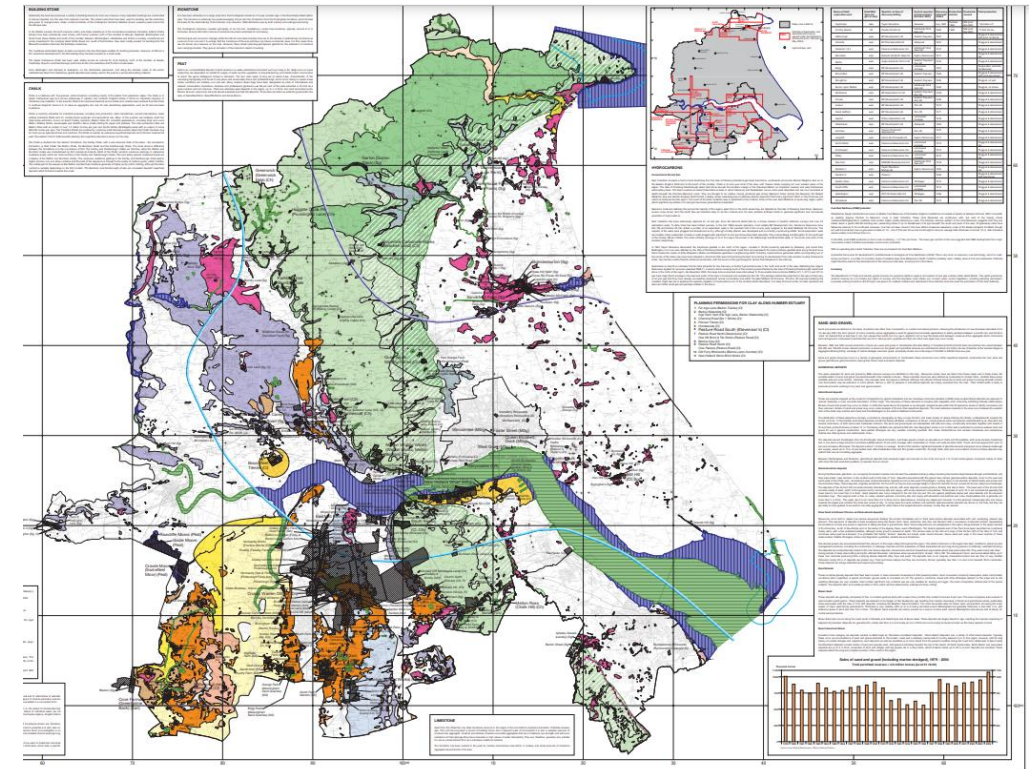
Positive feedback from industrial partners.

So far have done mapping and visualisation at **UK-wide scale**.

Can also make specific to:

- **Regions**
- **Individual plants**

Can apply to **other industrial sectors** (beyond steel, ceramics, glass, cement).



Humberside Mineral Resources Map
<https://www2.bgs.ac.uk/mineralsuk/download/england/humbersideMap.pdf>

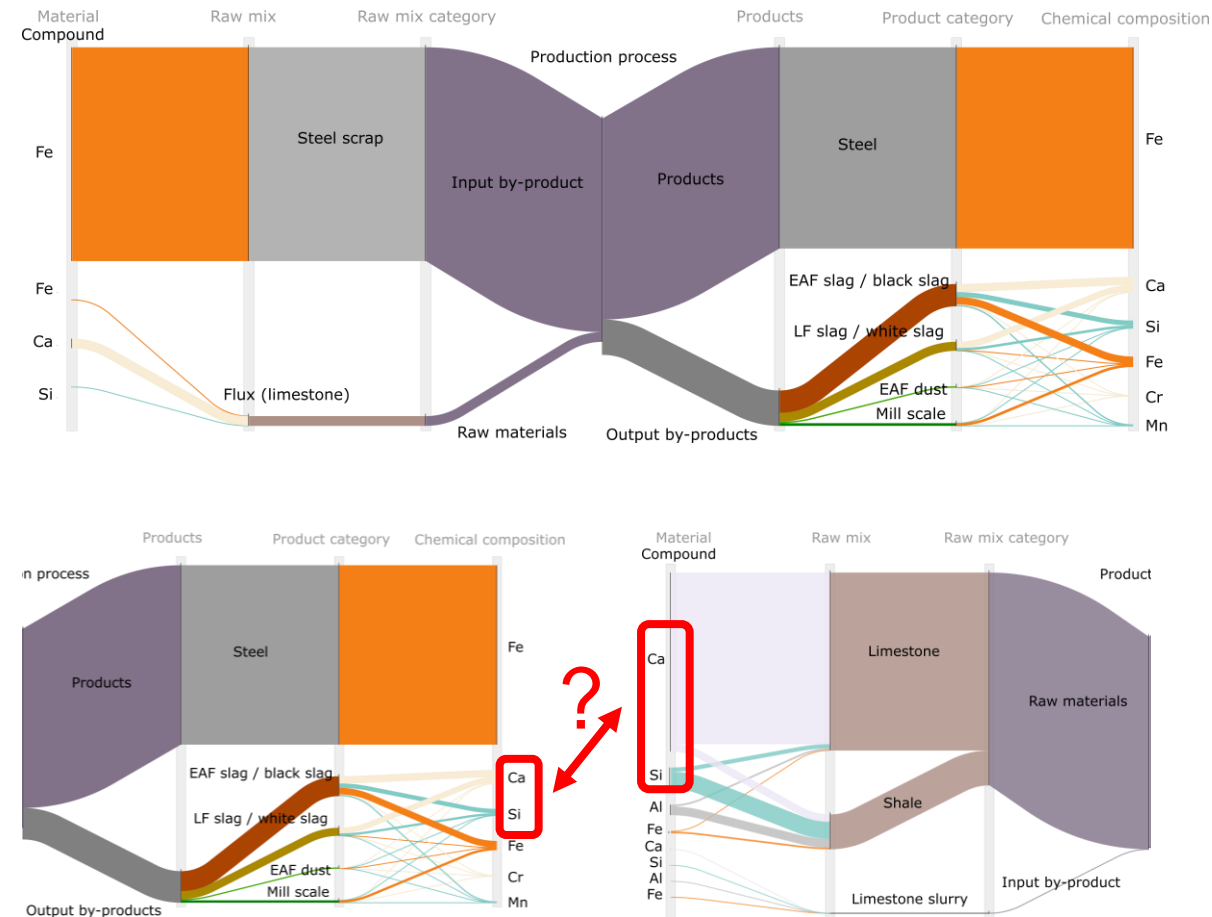
Conclusions and future research

1. Developed an approach of **element-based mapping** of material inputs and outputs
2. **Visualised** elemental flows in each sector using Sankey diagram
3. Identified **8x potential matches** for cross-sectoral industrial symbiosis

I. Make the matching process 'smarter' and **semi-automated**.

II. Enable matching of **multiple by-products** to substitute for a raw material input.

III. Make visualisation **simpler and more interactive**.



As a result ...



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EPSRC IAA “Developing the process and mix design for a carbon-neutral block using mineralized industrial waste” (£131k)



Innovate UK “CCSCOC - novel energy-efficient carbon capture technology for mineralising carbon in molten waste to support heavy industry to reach net-zero” (£474k)



Thanks you for listening



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- Would you like more information about this project?
- Are you interested in working with us to apply this approach to your business?

Please contact:

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