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Transforming Foundation Industries Research and Innnovation Hub

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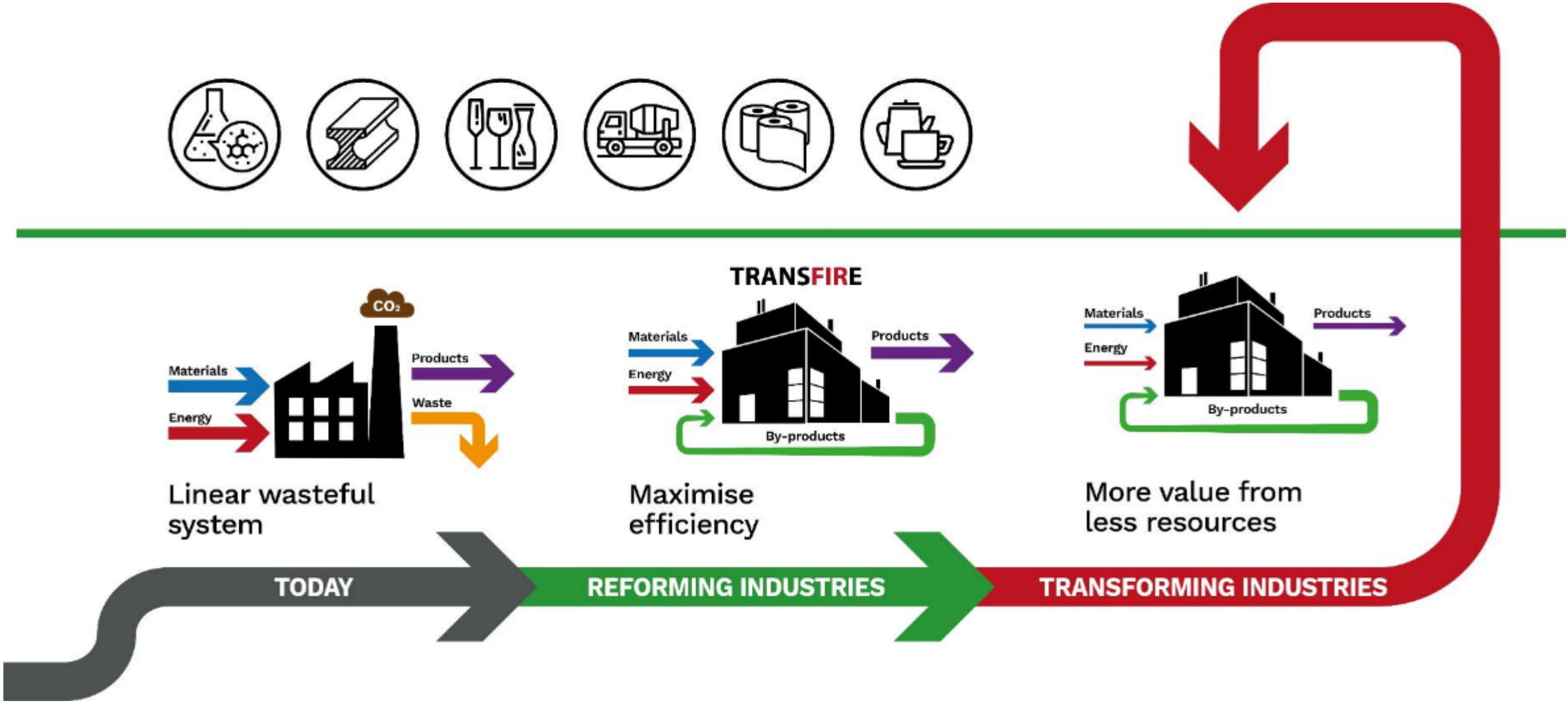
UK Research and Innovation

Analysing Resource Efficiency & Benchmarking of Foundation Industries

Jonathan Cullen

12 June 2024

TransFIRe



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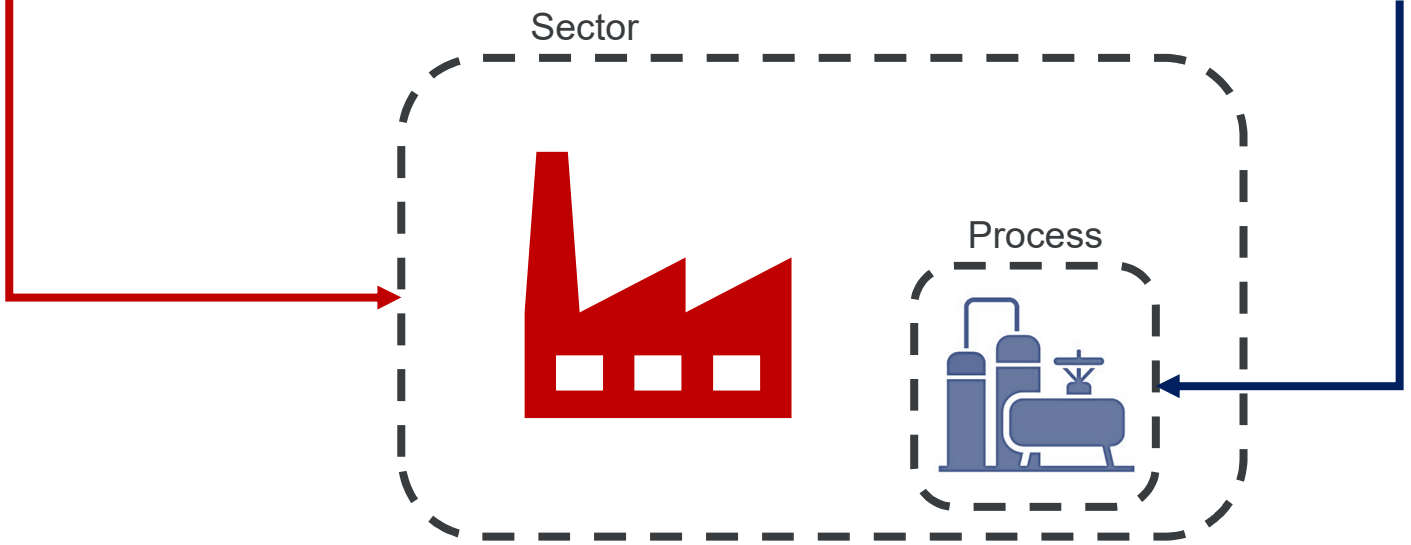

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Objectives

Provide a clear understanding of the foundation industries, where we are, and the potential to improve performance and become more sustainable.

→ Identify what is being manufactured

→ Quantify the energy and materials being consumed

→ Assess the current performance

→ Determine the potential for improvement

Approach

Mapping energy and material flows
Sectoral and process level

Benchmarking
Current performance
Best practices
KPIs
Material circularity

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WS1 - Cambridge

Natanael Bolson and Jonathan Cullen

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Sectors and Materials Mapped

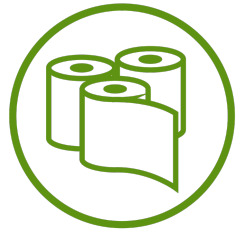
Cement
Cement

Ceramics
Refractory
Household
Tiles
Bricks

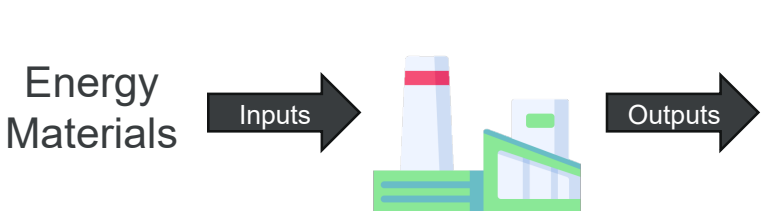
Chemicals
Ethylene
Ammonia
Propylene
BTX

Glass
Container
Flat
Filaments

Metals
Aluminium
Lead
Steel



Paper
Graphic
Packaging
Sanitary
Other



Gate to gate
Scope 1
Reference year 2019

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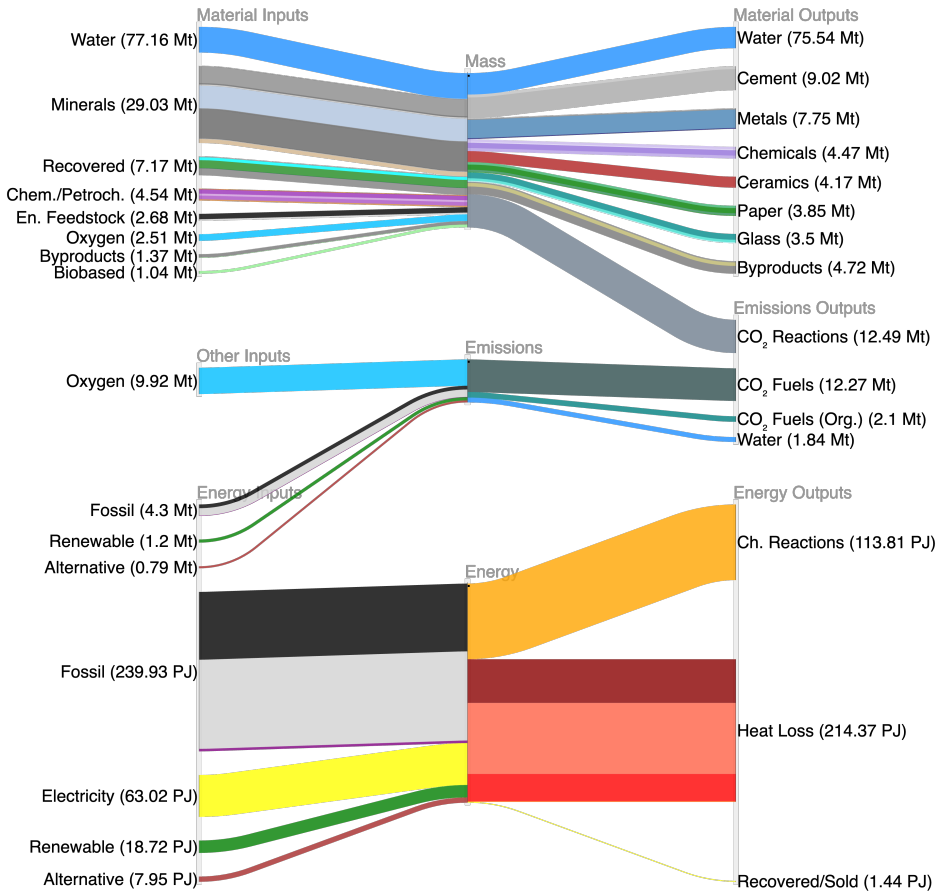
Resource Flows

Foundation industries



→ Enhanced transparency

→ Clear impacts of energy and material transformations

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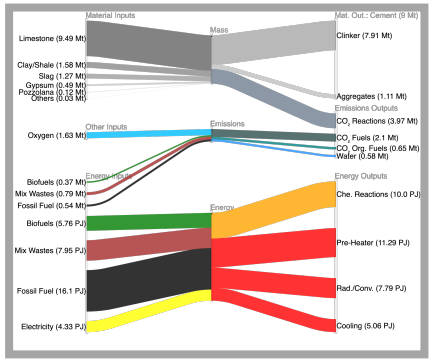
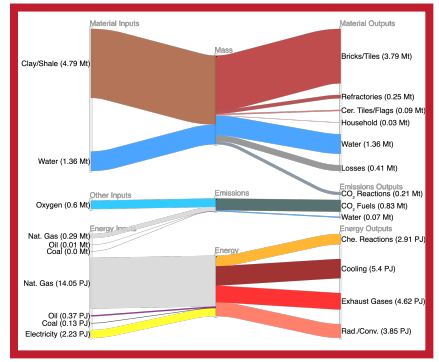
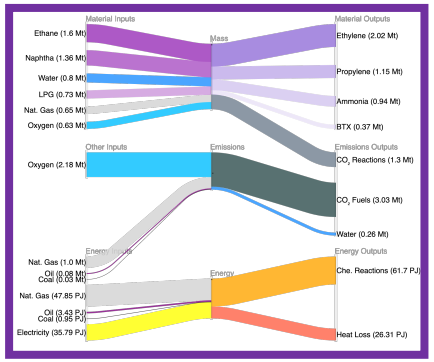
Cement



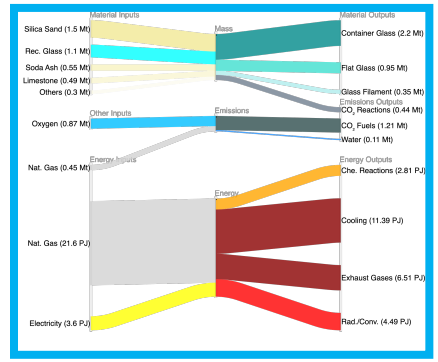
Ceramics



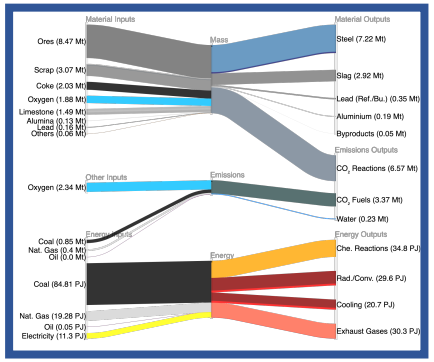
Chemicals



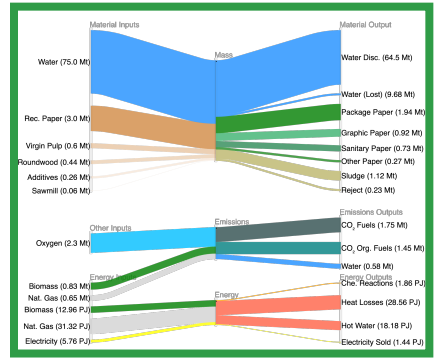
Glass



Metals



Paper



Foundation Industries in a Nutshell

	Cement	Ceramics	Chemicals	Glass	Metals	Paper
Materials	9 Mt	4.2 Mt	4.5 Mt	3.5 Mt	7.8 Mt	3.8 Mt
Emissions	6.7 $MtCO_2$	1 $MtCO_2$	4.3 $MtCO_2$	1.7 $MtCO_2$	9.9 $MtCO_2$	3.2 $MtCO_2$
Energy	34 PJ	17 PJ	88 PJ	25 PJ	115 PJ	50 PJ

Perspective

Manufacturing

45% Material footprint

37% CO_2 emissions

39% Energy used

Provide

33 Mt of materials

Use

330 PJ of energy

Emit

CO2

27 $MtCO_2$

47 % Process **53 %** Energy

UK

5% Material footprint

6% CO_2 emissions

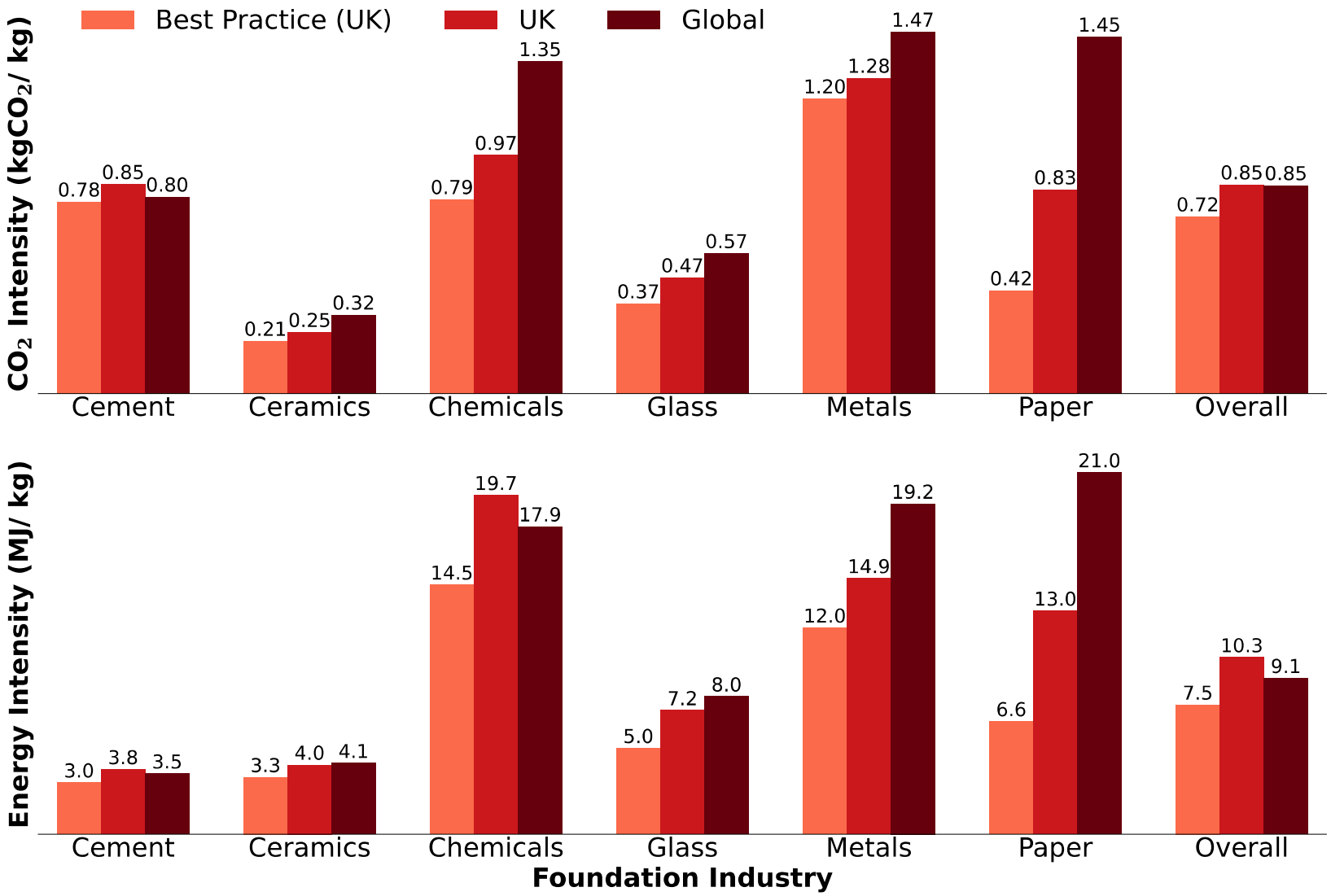
6% Energy used

Emissions and Energy Intensity

→ Clean energy systems can hide poor energy performance

→ Overall performance is a weighted average, reflecting societal needs

→ Best practices provide a feasible target to pursue

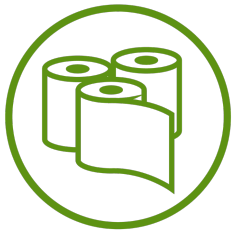


*Cement units normalised for clinker output

Potential Decarbonisation





	Cement	Ceramics	Chemicals	Glass	Metals	Paper
Current	6.7 $MtCO_2$	1 $MtCO_2$	4.3 $MtCO_2$	1.7 $MtCO_2$	9.9 $MtCO_2$	3.2 $MtCO_2$
Best practices	6.2 (-8%)	0.9 (-14%)	3.5 (-18%)	1.4 (-18%)	9.3 (-7%)	1.6 (-50%)
Clean fuels	4 (-41%)	0.2 (-80%)	1.3 (-70%)	0.5 (-70%)	6.6 (-34%)	0 (-100%)

Current

27 $MtCO_2$

47 % Process **53 %** Energy

Best Practice

23 $MtCO_2$

55 % Process **45 %** Energy

15% reduction

Clean fuels

13 $MtCO_2$

100 % Process **0 %** Energy

52% reduction

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Material Circularity

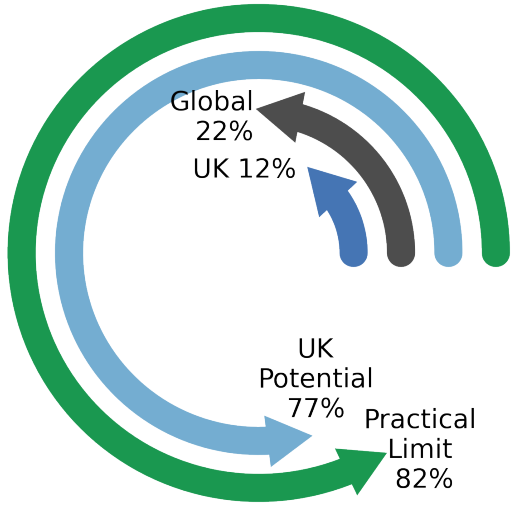
- → Circularity benefits are dependent on the type of material
- → Greater energy differences between primary and secondary production increase the benefits of adopting circularity
- → Practical limits reflect current technological limitations

$$CI = \alpha \times \beta$$

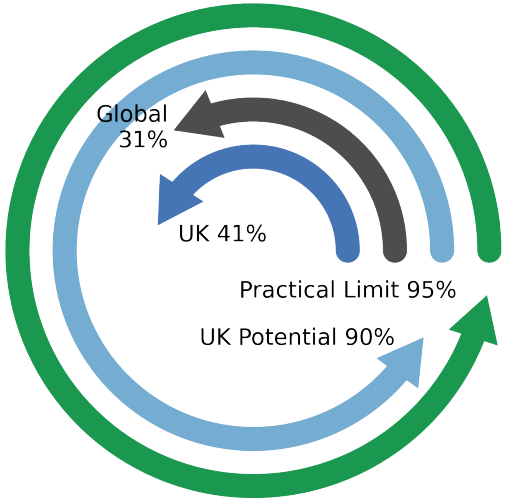
$$\alpha = \left(\frac{\text{Recovered EOL material}}{\text{Total material demand}}\right)$$

$$\beta = \left(1 - \frac{\text{Secondary production energy use}}{\text{Primary production energy use}}\right)$$

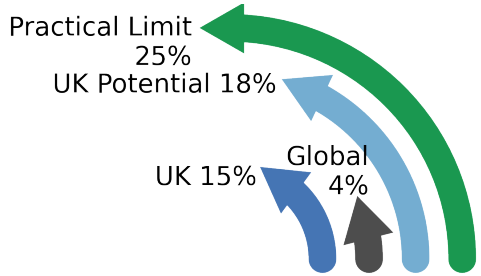
Cullen (2017)



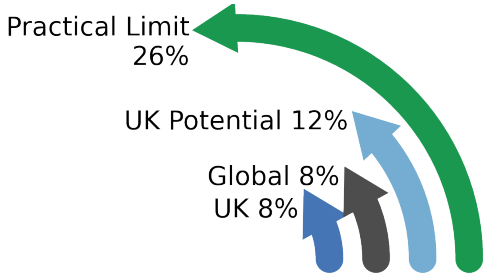
Steel



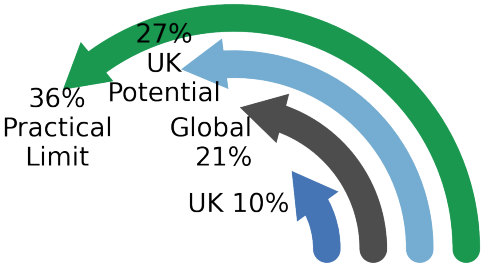
Aluminium



Lead

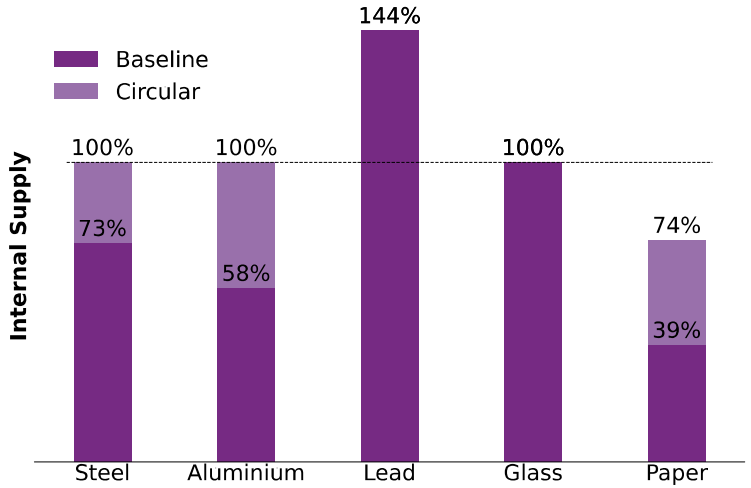


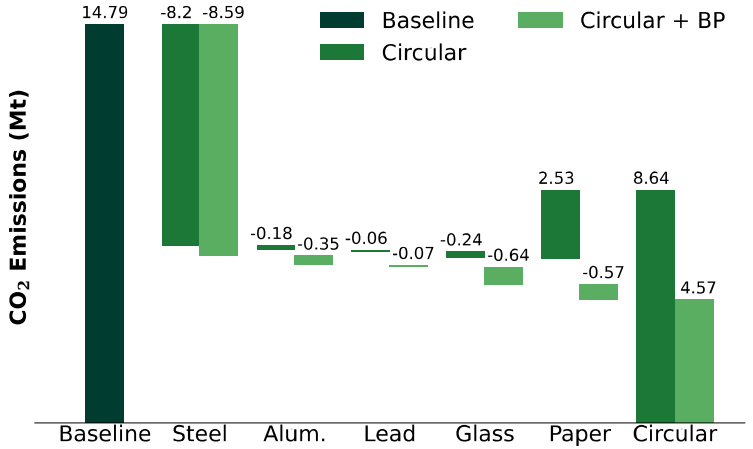
Glass

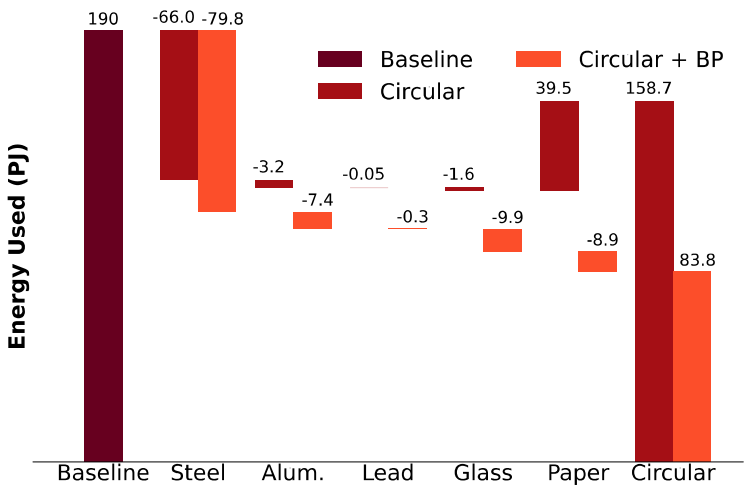


Paper

Outcomes of Material Circularity







→ Adopting circularity can increase resilience of the supply chain

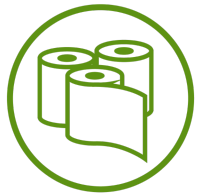
→ The benefits of circularity reflect current levels already reached

→ For metals, circularity is the most important step!

→ Circularity combined with best practices is the key to sustainability

Potential Decarbonisation due to Circularity





	Glass	Metals	Paper
Current	1.7 $MtCO_2$	9.9 $MtCO_2$	3.2 $MtCO_2$
Circular	1.4 (-18%)	1.5 (-85%)	5.7 (78%)
Circular + BP	1.0 (-41%)	0.9 (-91%)	2.6 (-19%)

Material circularity + BP + clean fuels

0.43 $MtCO_2$

97% reduction in emissions!

Foundation industries:

From **27 $MtCO_2$** to **6 $MtCO_2$** (**78%** reduction)

Current

15 $MtCO_2$

47 % Process **53 %** Energy

Circular

8.6 $MtCO_2$

5 % Process **95 %** Energy

43% reduction

Circular + BP

4.6 $MtCO_2$

9 % Process **91 %** Energy

70% reduction

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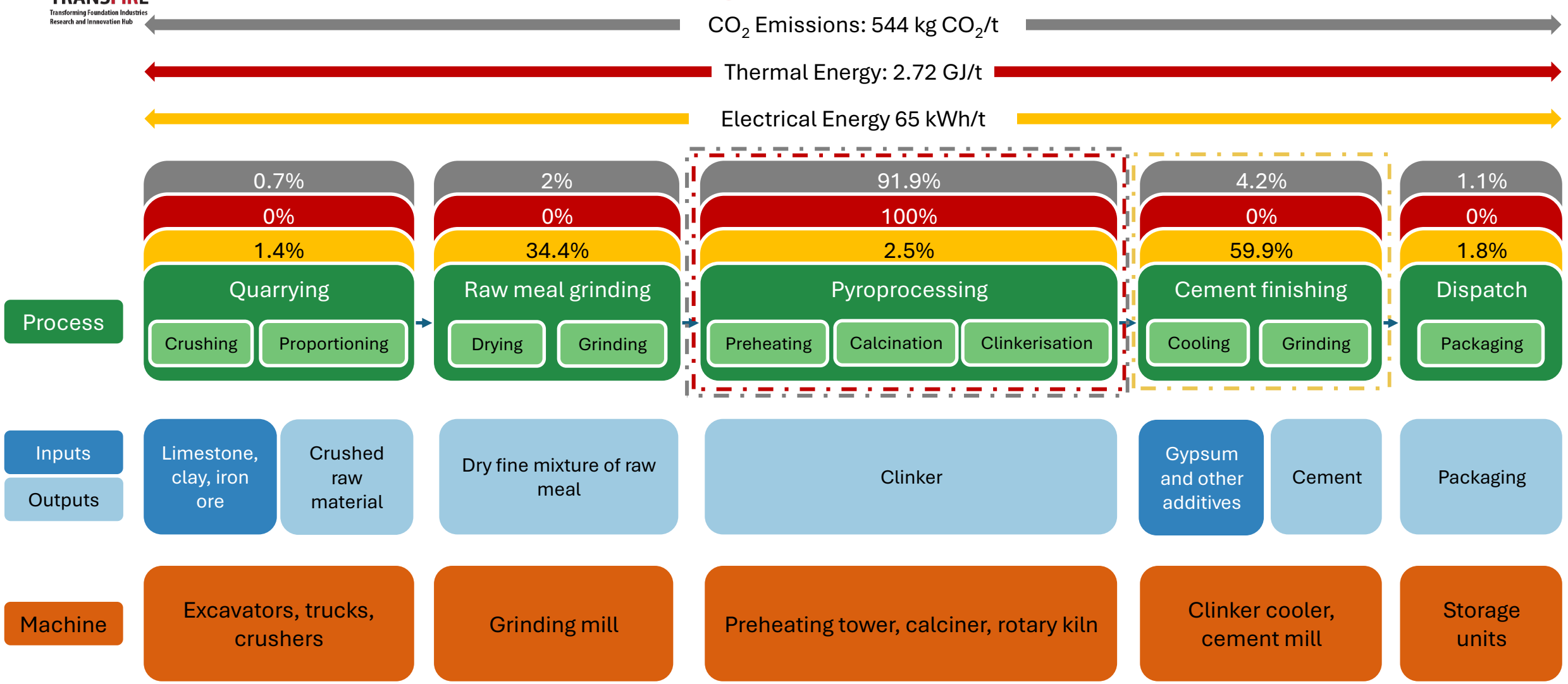
Process Mapping

Cement Manufacturing



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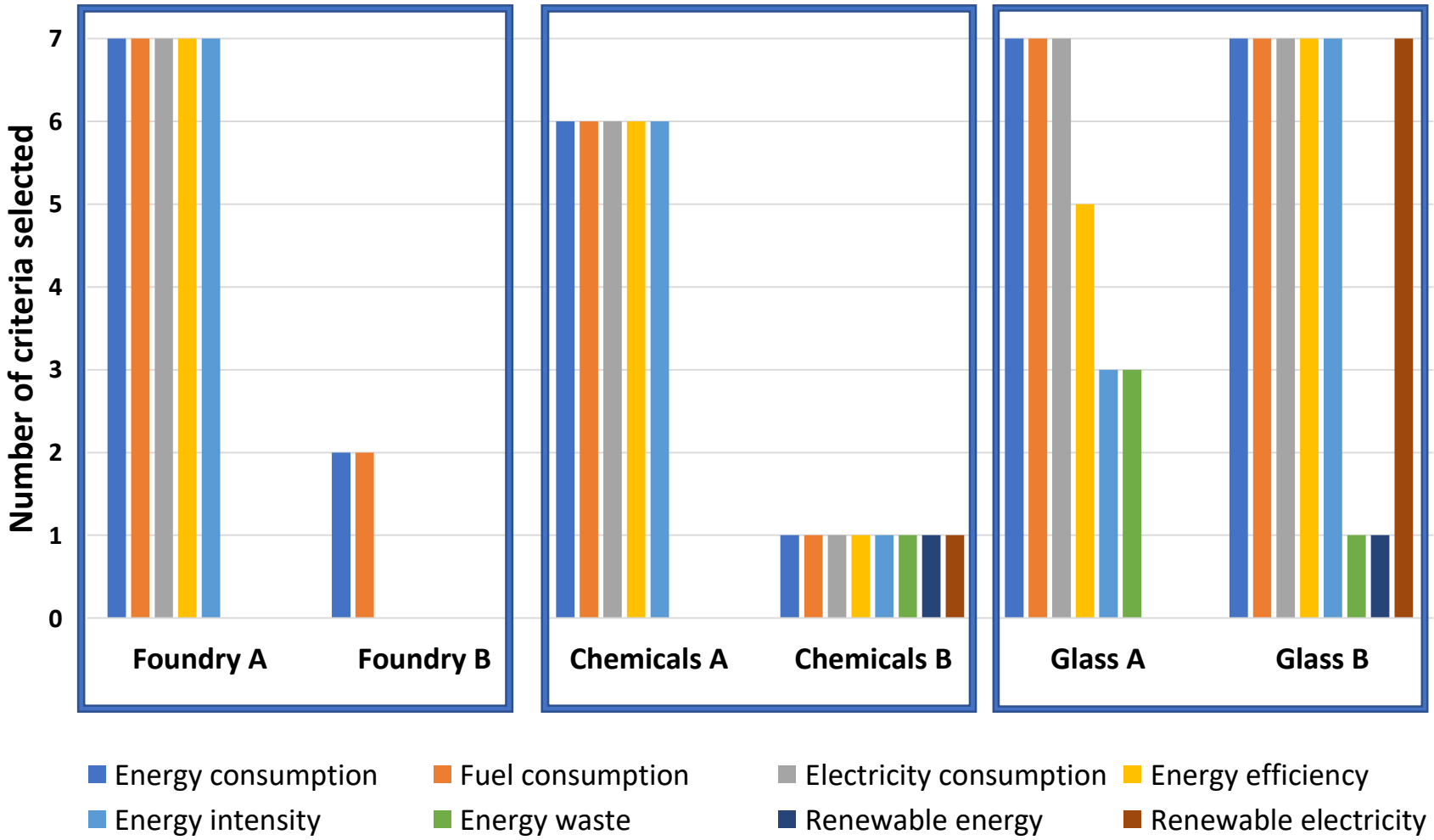
KPIs Analysis

Criteria	
1	Quantifiable
2	Relevant
3	Understandable
4	Accurate
5	Comparable
6	Documented
7	Trackable



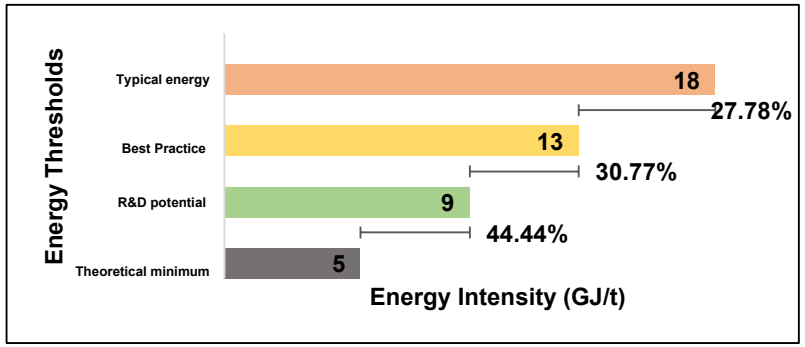
Full details available at: https://doi.org/10.1016/j.procir.2023.09.188

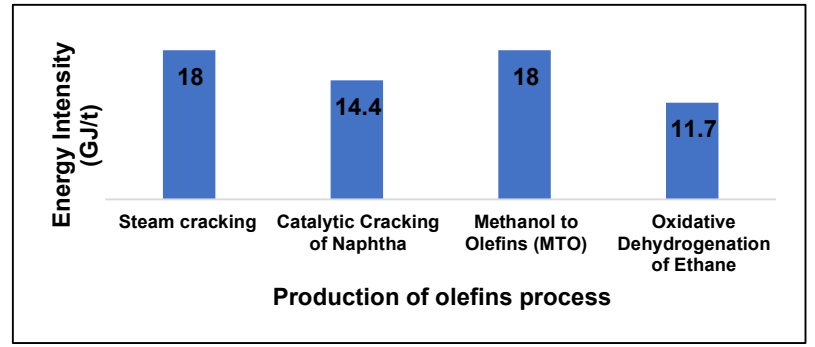
Theoretical Minimums

Energy thresholds

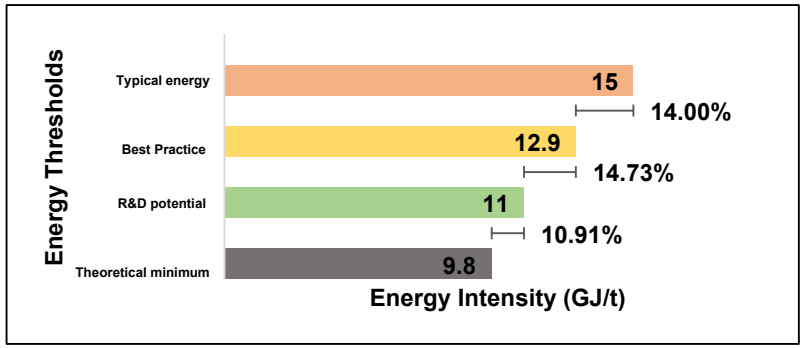
Alternative Technologies

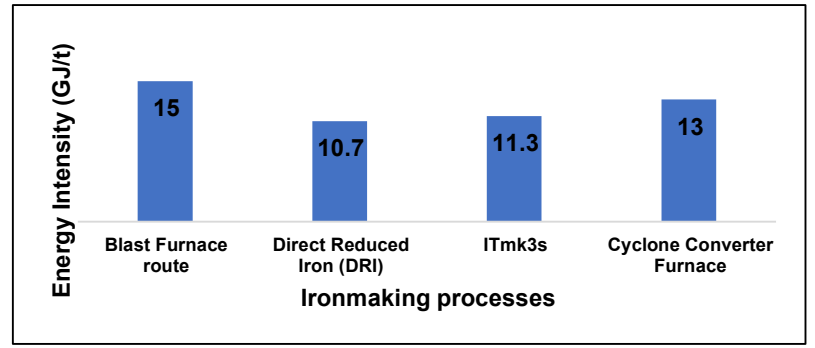
Steam cracking



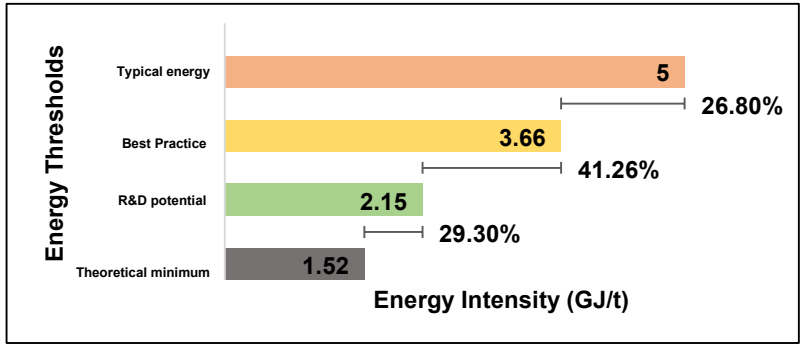


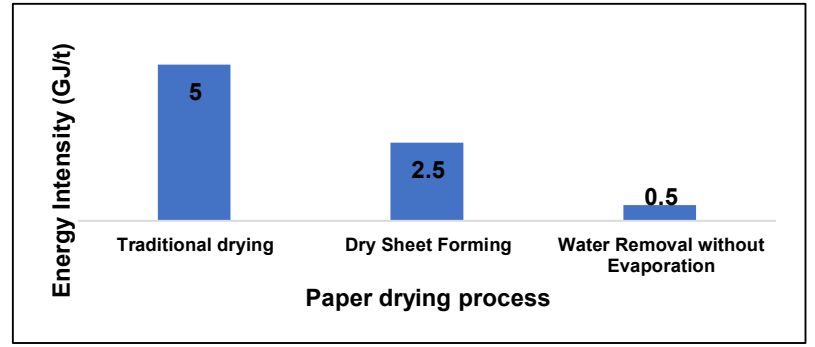
Iron Making





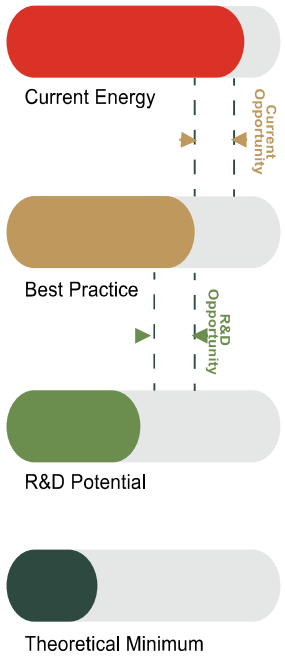
Paper Drying





Minimums

Steam cracking



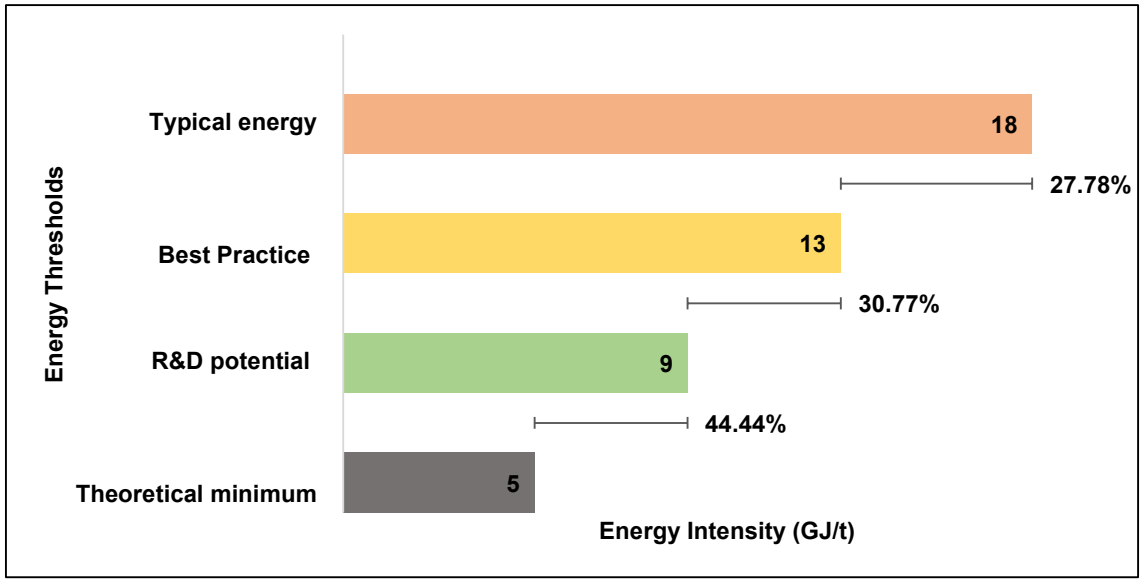
The current energy consumption for the process in the industry.

The energy consumption that may be possible through the adoption of existing best technologies available.

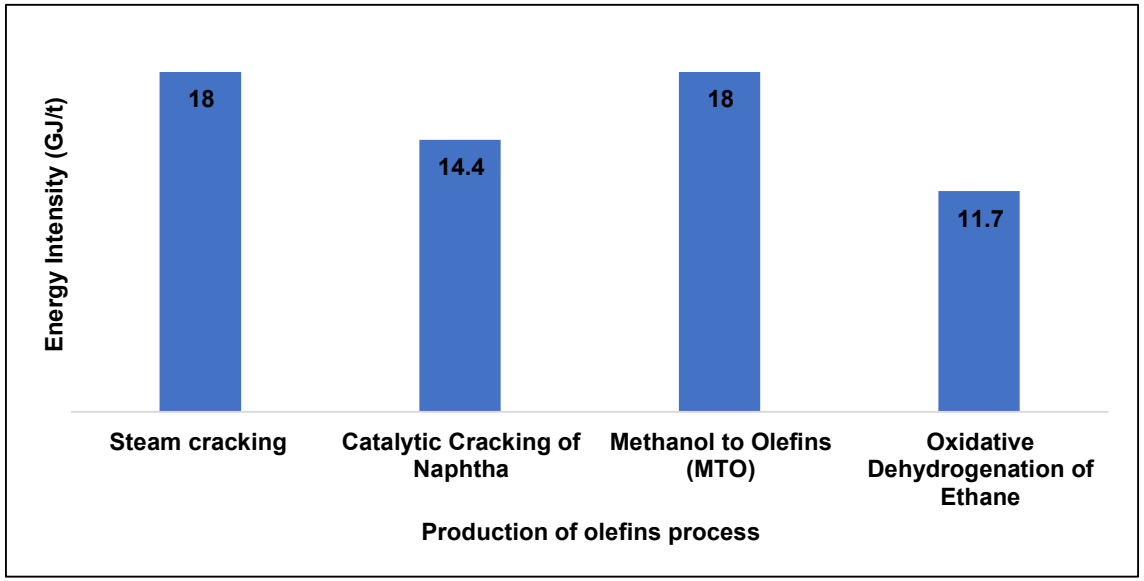
The energy consumption that may be possible if (R&D) technologies under development are deployed.

The least amount of energy required under ideal conditions.

Energy thresholds

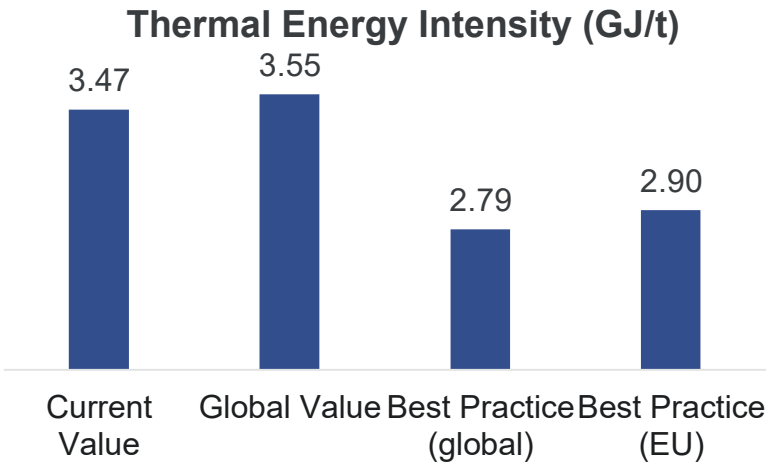


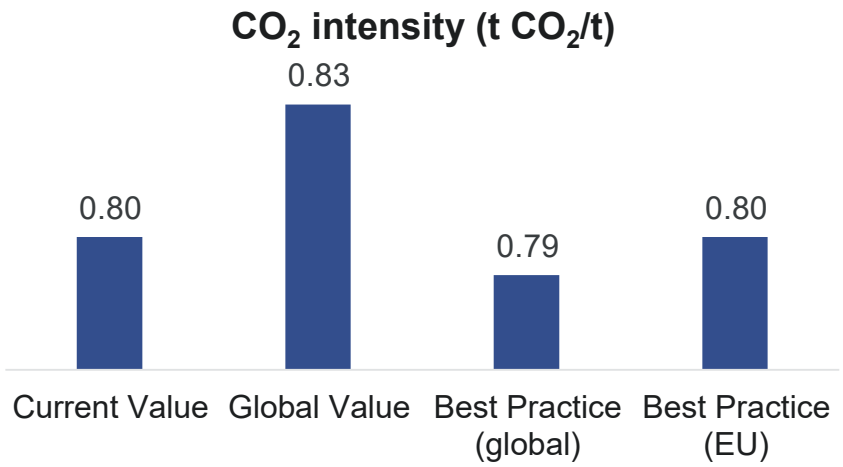
Alternative Technologies

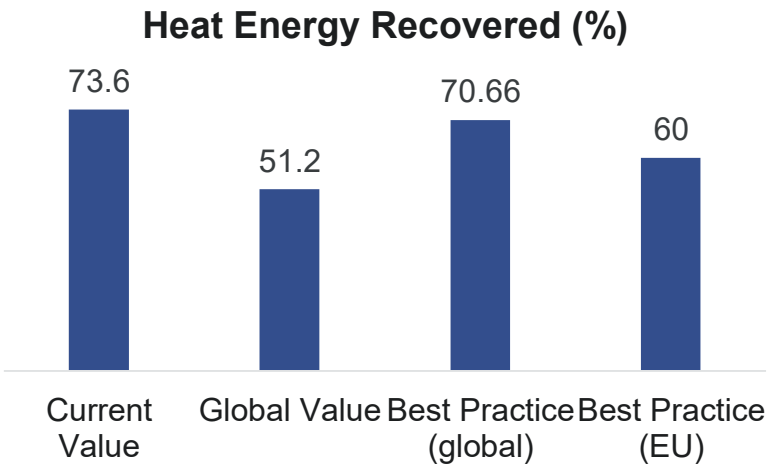


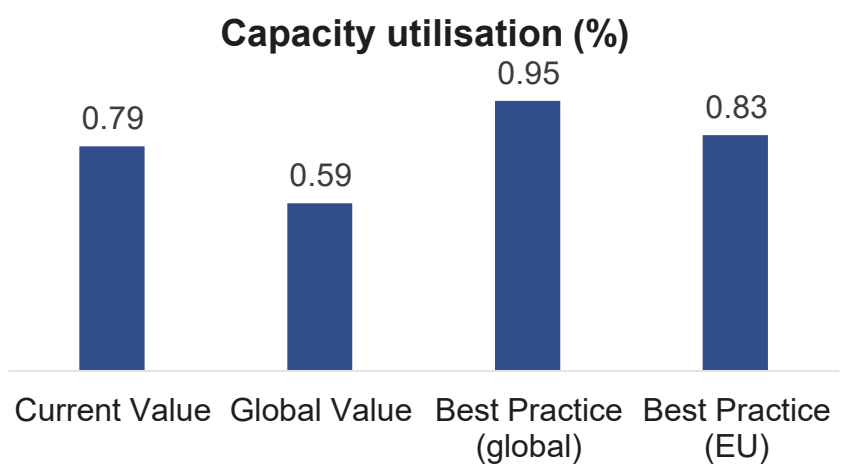
Benchmarking – Case Study

Clinkerisation









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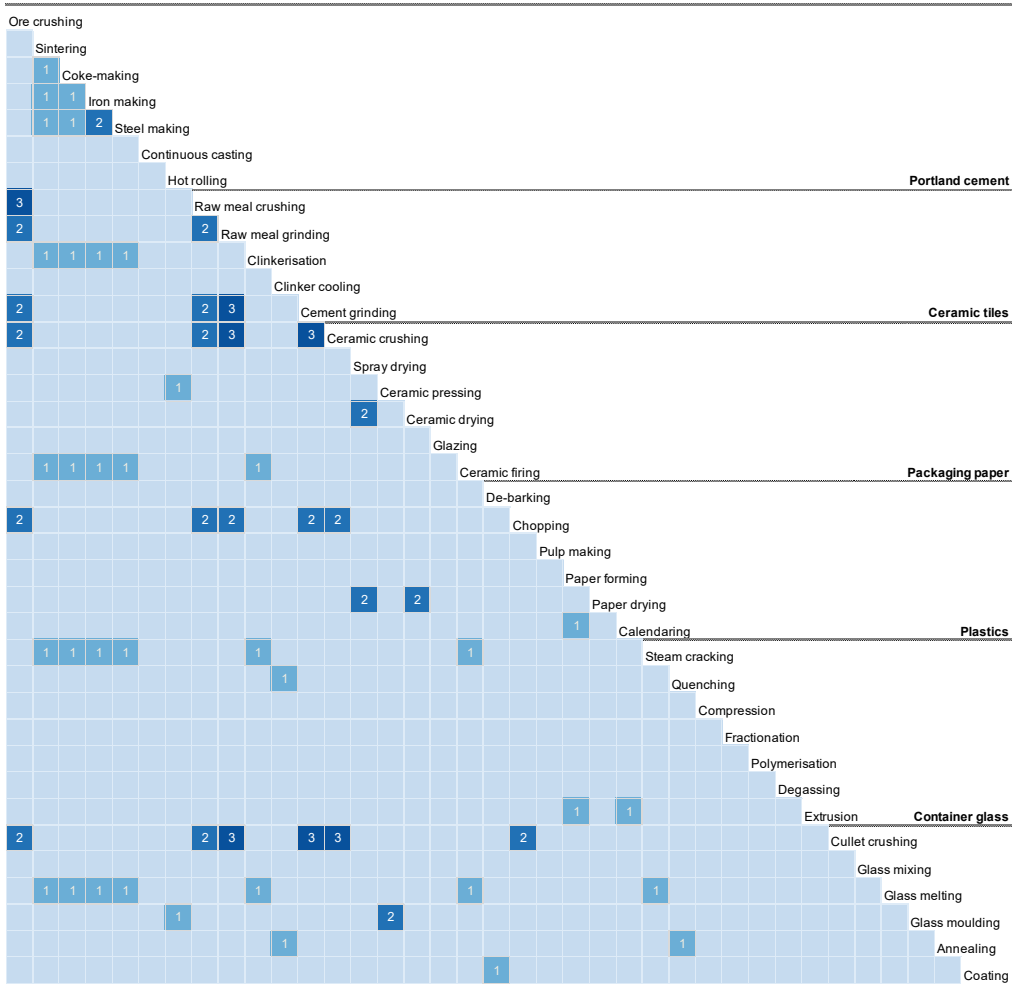
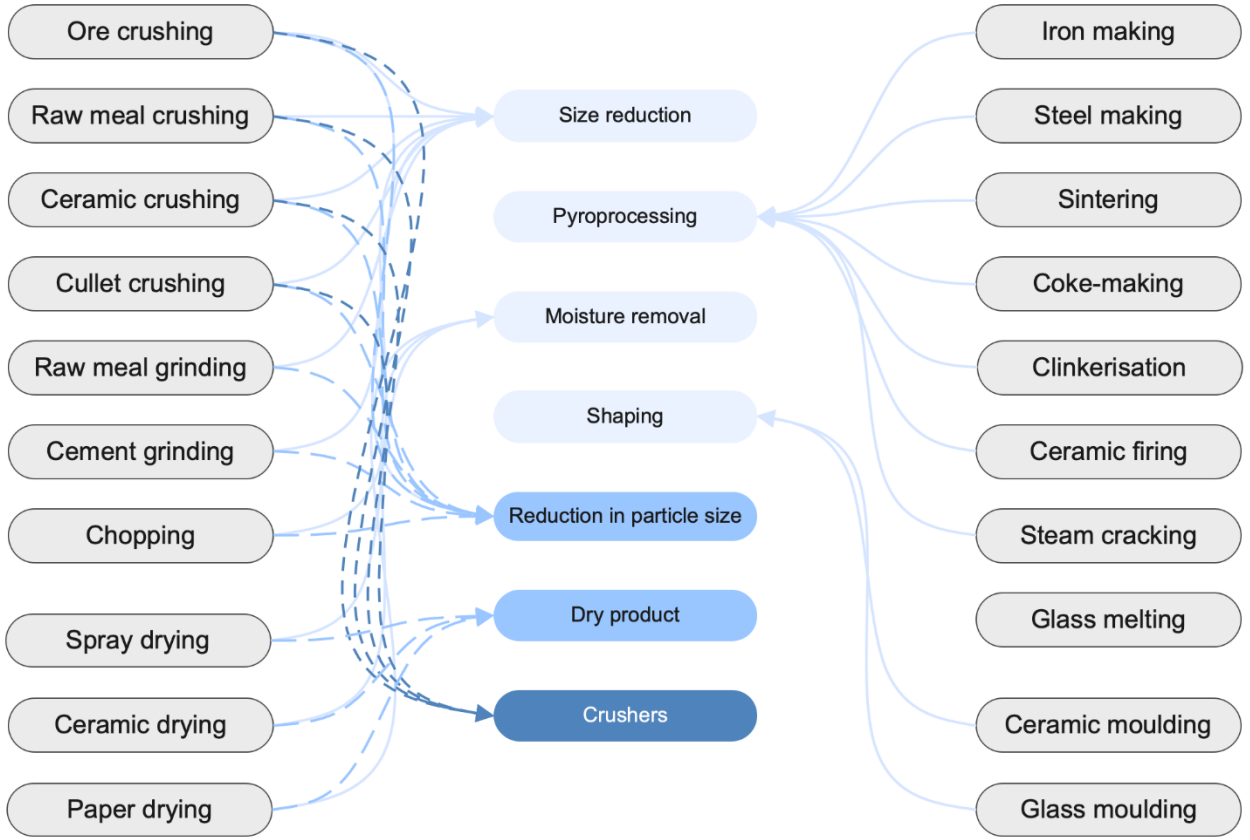
Full details available at: https://doi.org/10.1007/978-3-031-50244-6_5

Process Commonality





Principle	1
Outcome	2
Equipment	3

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Full details available at: https://doi.org/10.3390/su151914422

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Summary

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Summary I

→ Resource flows in the foundation industries have been mapped

→ Clear assessment of status

→ Identified potential for improvement in different sectors

→ Assessed the impact of decarbonisation levers

→ Adoption of best practices (up to **15** %)

→ Cleaner fuel mix (up to **52** %)

→ Material circularity (up to **78** %)

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Summary II

→ Detailed analysis of process provides clarity on where the impacts occur

→ Guidance on where efforts should be focused

→ Energy KPIs

→ Lack of clear standard in energy metrics across sectors

→ Preference for easily measurable metrics (e.g., electricity) or with identifiable benefits (e.g., renewable energy)

→ Identified commonality between process

→ Enables cross-sectoral insights to adopt best practices and technologies

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Thank you!