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Foundation Industries Sustainability Consortium

FISC Strategy Workshop

The Foundation Industries Sustainability Consortium (FISC) brings together global leaders in innovation, research and technology from across the cement, metal, glass, ceramic, paper, polymer and chemical industries.

UKRI Innovate UK

FISC Summit

Government Landscape

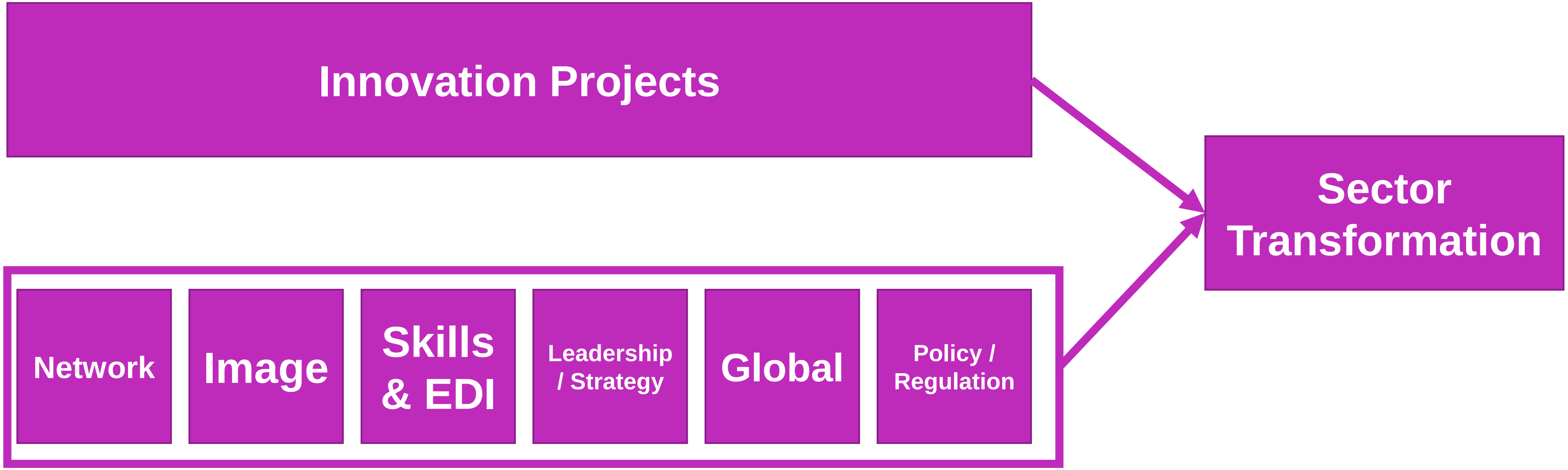
Foundation Industries

Department for Business and Trade	Department for Science, Innovation and Technology	Department for Transport

Sector Transformation

Innovate UK

Key to the success of TFI has been the interconnectedness of the various parts of the challenge. Innovation is a cornerstone of transformation, but a wider collection of interventions are needed.



Innovate UK

What We Need

Comms Message	Ask of Community	Call to action for Government
Programme successes	Give clarity on what is needed for sector transformation.	Understand their role in the transformation plan.
Credible Foundation Industries	Raise the profile of the Foundation Industries and their innovation thus far. Amplify TFI comms.	Understand the credibility of the transformation plan.
Vision for the future	Unite in the adoption of Foundation Industries terminology and collaborative mindset.	Value the Foundation Industries as a collective with a clear future in the UK.

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Innovate UK

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FISC Vision

Strengthen the foundation industries in the UK by working together

<u>To</u>

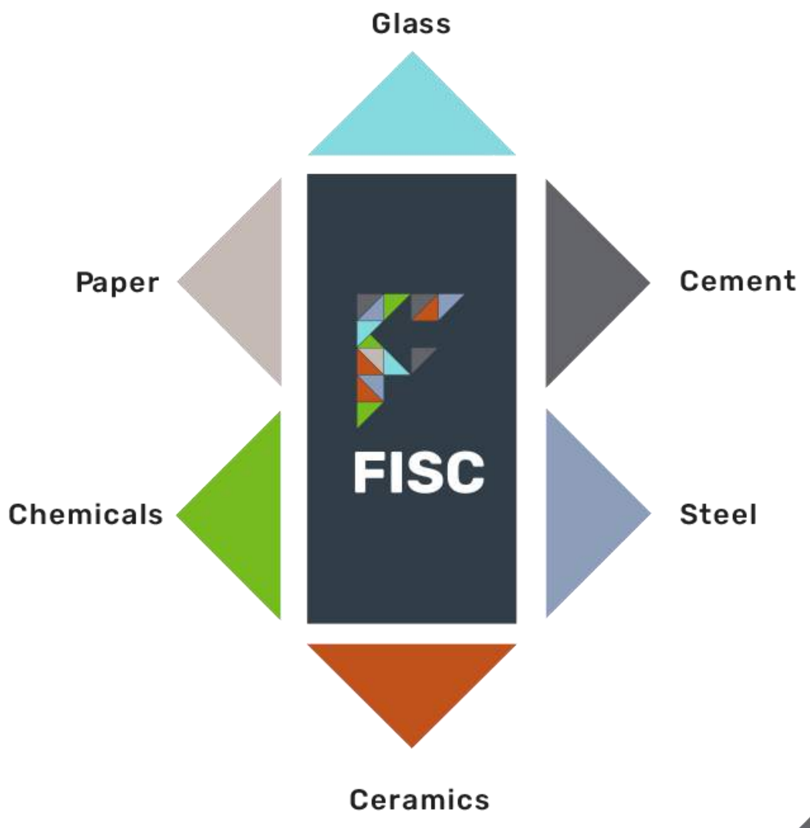
Scale and Accelerate the Innovation needed to drive the transformation of the foundation industries

<u>In order to create</u>

Sustainable, low carbon and resource efficient materials delivered to vital *Supply Chains*

<u>Enabled by a</u>

Skilled and Diverse Workforce with exciting jobs in vibrant industries that support the UK economy.



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cpi

CPI connects the dots within the innovation ecosystem to make great ideas and inventions a reality. We're a pioneering social enterprise that accelerates the development, scale-up and commercialisation of deep tech and sustainable manufacturing solutions. As a trusted partner of industry, academia, government, and the investment community, we're the catalyst that delivers sustainability and healthcare innovations to benefit people, places, and our planet.

Materials Processing Institute

The Materials Processing Institute supports innovation for a sustainable future through materials development and process improvements, which are delivered by project teams utilising state-of-the-art equipment, laboratories, workshops, demonstration, scale-up and production facilities. Research, development, and innovation is focused on advancing materials performance, achieving industrial decarbonisation through a low carbon and hydrogen future, deploying new digital technologies, and reducing waste through a circular economy.

Glass Futures

A not-for-profit membership organisation, Glass Futures connects the global glass industry and academia to deliver R&D and innovation, ensuring glass making's future is built on high value and fully sustainable, zero-carbon products. In collaboration with industry, it has delivered the world's first openly accessible, commercially available, multi-disciplinary glass melting facility, the Global Centre of Excellence.

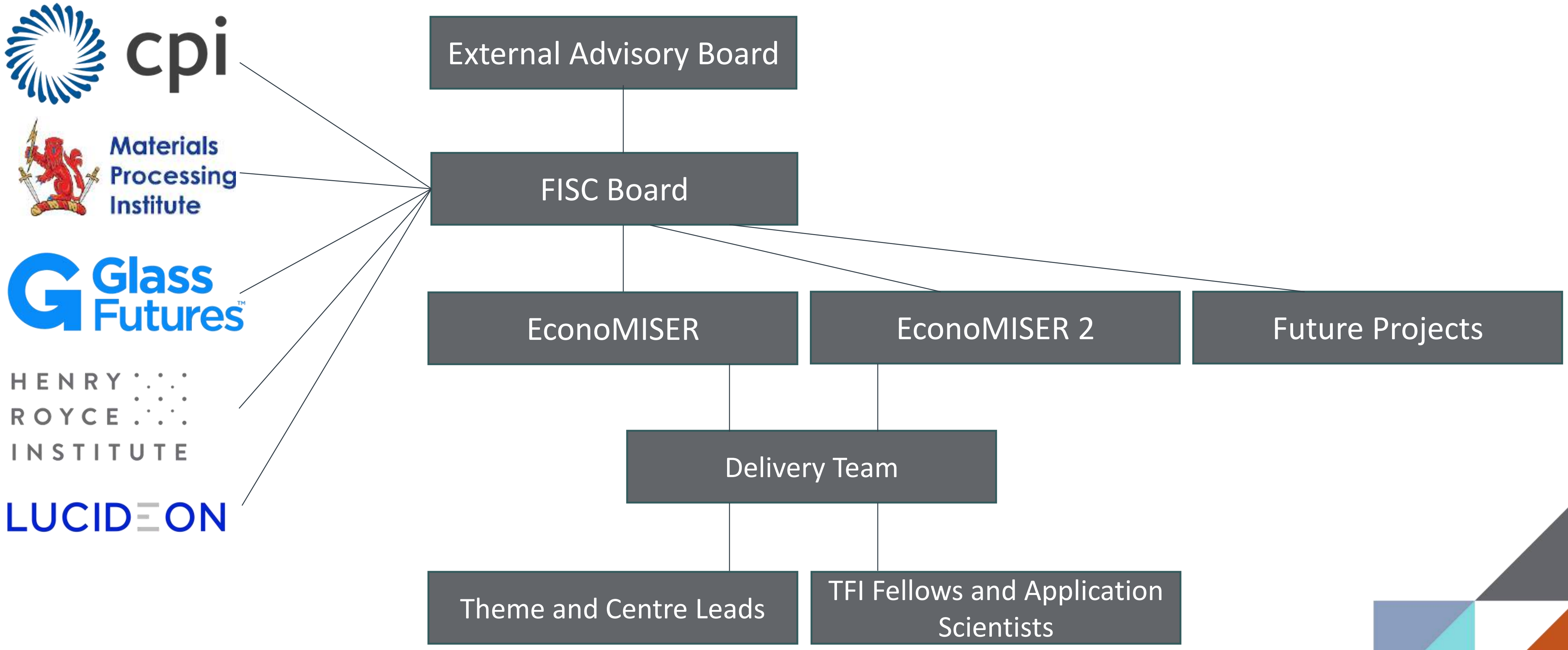
Henry Royce Institute

The Henry Royce Institute (Royce) is the UK's national institution for advanced materials research and innovation. Providing access to world-class research capabilities, infrastructure, expertise, and skills development, Royce works with the UK materials community to develop solutions to national and global challenges.

Lucideon

Lucideon specialises in materials technology, processes, and testing. Its application of cross-industry insight, materials science expertise, and innovative thinking allows industry to develop and implement disruptive technology platforms, providing cost and/or product performance benefits. It utilises its many years of experience in development, analysis, and assurance to provide technical consultancy to accelerate its clients' R&D activities.

FISC Governance



Infrastructure for collaboration

A presumption in favour of collaboration on Foundation Industry Innovation

Five globally leading research and technology centres with a proven track record who have agreed to collaborate their expertise and R&D capability

Collaboration with industry supported by:

- 3 Industry Fellows,
- 1 Senior Application Scientist,
- 3 Application Scientists, and
- 5 thematic leads from the FISC partners

Collaboration between centres to develop shared solutions, learn from best practice and to innovate across the Foundation Industry sectors

Future collaboration with other innovation and R&D programmes

Offer to the Foundation Industries

- Establish a network of scale-up centres to support the Foundation Industries.
- Deliver cross centre working to address innovation challenges around decarbonisation and sustainability.
- Increase industry engagement in scale-up activities and innovation in the UK.
- Devise a plan to develop a workforce capable of delivering net zero and a circular economy.
- Deliver the EconoMISER Programme:
    - Upgrade scale-up facilities to enable a more sustainable Foundation Industries.
    - Support translational research through the deployment of Application Scientists.
    - With the support of Transforming Foundation Industry Fellows, develop a strategy for translational research in consultation with the manufacturing sectors.

FISC Delivery Model

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Connect

TFI Fellows will engage with companies and RTOs to landscape the national research & innovation challenges faced by the foundation industries and identify project partnerships for EconoMISER.

This connection will **establish cross sector links** throughout technology and manufacturing readiness levels to initiate projects that will extend beyond the lifecycle of EconoMISER.

Collaborate

EconoMISER Application Scientists will work alongside two or more members of FISC and external project partners to deliver R&D solutions for the Foundation Industries.

FISC is comprised of five research facilities who can offer a wide range test facilities and expertise to help **identify solutions to research and innovation challenges** faced by the foundation industries.

Innovate

The **EconoMISER team** and **project partners** will develop identified solutions through the network of scale-up centres established by FISC and roll out technology and manufacturing solutions into the Foundation Industries.

EconoMISER is organised around five research themes and will use FISC facilities to **scale-up research through technology and manufacturing readiness levels**

Impact

EconoMISER projects will support the decarbonisation and sustainability needs of the **Foundation Industries** through improved resource efficiency, sustainable products and Industry 4.0 solutions.

Outcomes will add security to raw materials supply chains, improve cost competitiveness, accelerate digitisation, and advance skills & diversity within the workforce.

	Connect	Collaborate	Innovate	Impact
Stakeholder(s):	UK Foundation Industries Community; Foundation Industries Sustainability Consortium	FISC Partners; Foundation Industries Partners	FISC Partners; Foundation Industries Partners	UK Foundation Industries Community
Supported by:	TFI Fellows	Application Scientists	EconoMISER Scale-Up Centres	FISC Partnership

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Delivery Strategy

6-12 months	12-24 months	Future Aims	Industry led innovation
Scale Up Foundation Industry Innovation Centres	Respond to Critical Foundation Industry Needs	Industry led, utilising Innovation Centre Capability	
Identifying industry challenges	Industry facing collaboration	Future Transforming Foundation Indsutry Programmes	
Establishing collaboration across centres	Laying the ground work for future programmes	Focus on people, materials and fuels	

EconoMISER

Economy | Materials | Innovation | Sustainability | Efficiency | Resources

EconoMISER is the first major project of FISC, representing a £19.5m investment by UK Research and Innovation.

The objectives for EconoMISER is to:

- establish a network of scale-up centres to support the foundation industries (FI);
- upgrade scale-up facilities to enable a more sustainable FI;
- develop a business case for a sustainable network beyond 2024;
- increase industry engagement in scale up and innovation in the UK;
- deliver cross centre working between the facilities to address innovation challenges around sustainability; and
- deliver a plan to transform a workforce fit to deliver net zero for the FI.

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The EconoMISER project is structured to drive the delivery of these **themes that are critical to** the creation of a **zero carbon** resource efficient sustainable foundation industry in the UK.

Alternative fuels

Circular economy, feedstock, recycling and reuse

Digital control and sensors

Process optimisation

Sustainable materials development

EconoMISER 2

£18m investment by UKRI in 2024/25 to help enable the transition to Net Zero for the foundation industries requires specialist facilities that enable companies to trial new technologies at scale.

This programme proposes to provide additional capabilities to five facilities that will provide the key infrastructure needed to demonstrate low carbon technologies at scale.

The aim of EconoMISER 2 is to upgrade facilities that address the challenge of reducing the impact of material production within the Foundation Industries (FI) across the 5 FISC Themes.

The objective for the EconoMISER 2 project within the network of FISC facilities is to:

- establish a network of scale-up centres to support the foundation industries (FI);
- upgrade scale-up facilities to enable a more sustainable FI;
- develop a business case for a sustainable network beyond 2024;
- increase industry engagement in scale up and innovation in the UK;
- deliver cross centre working between the facilities to address innovation challenges around sustainability; and
- deliver a plan to transform a workforce fit to deliver net zero for the FI.

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EconoMISER 2

	Work Package / Theme	Circular Economy	Sustainable Materials	Alternative Fuels	Process Optimisation	Digital Controls
WP1	Enhancing Alternative Fuals Capabilities			✓		
WP2	Refractory test Centre for Alternative Fuels			✓		
WP3	Paper Innovation	✓				
WP4	Multi-purpose Plastics Recycling	✓				
WP5	Federated Learning to Enhance Process Control and Optimisation					✓
WP6	Furnace Modelling & Heat Flow Optimisation				✓	
WP7	AI Driven Sustainable, Next Generation Alloy Development		✓			
WP8	Sustainable Cement Testing and Development		✓			
WP9	Chemical Feedstocks Replacement		✓			
WP10	FIVe	✓	✓	✓	✓	✓

Emerging ideas – longer term

The longer-term projects include:

- Hydrogen Fuels, expanding the sector's capability to generate and use hydrogen at scale.
- Digital Twins, big data approach to developing predictive technologies in foundation industries.
- Net Negative Industrial Cluster, alignment of industrial waste streams to resource requirements to create net negative emissions.
- Co-Location Symbiosis, drawing together pilot scale facilities from across 3 FI sectors.
- Foundation Industry Resource Mapping (FIRM-CIRCLE), improve UK FI circularity (linked to the Net Negative Industrial Cluster concept).
- Greening Industry Accelerator, support development of industry decarbonisation options.
- Resource Efficiency, project to evaluate and align material flows through FIs.
- Foundation Industry Ventures (FIVe). Creating a system, network and location that can facilitate and support the successful commercialisation of new businesses within the Foundation Industries with a particular emphasis on SMEs.

Key issues

- Engagement with Industry partnerships to define shared challenges – HRI Fellows and Application Scientists a valuable resource in exploring ideas and project concepts
- General resource favouring capital investment – further investment in equipment important, but as important is the human resource to collaborate and work across industry and RTO centres
- Sprint nature of project development and delivery poses challenges as resource stretched across procurement, implementation, collaboration and engagement with industry
- Secure the sustainability of FISC itself through agreement to a new business model, less reliant on project finance.

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Contact us to discuss how we can help you solve your innovation challenges:

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www.ukfisc.org

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Alternative Fuels Theme

Dr Bridget Stewart, Glass Futures| 20th March 2024

HENRY ROYCE INSTITUTE

Glass Futures

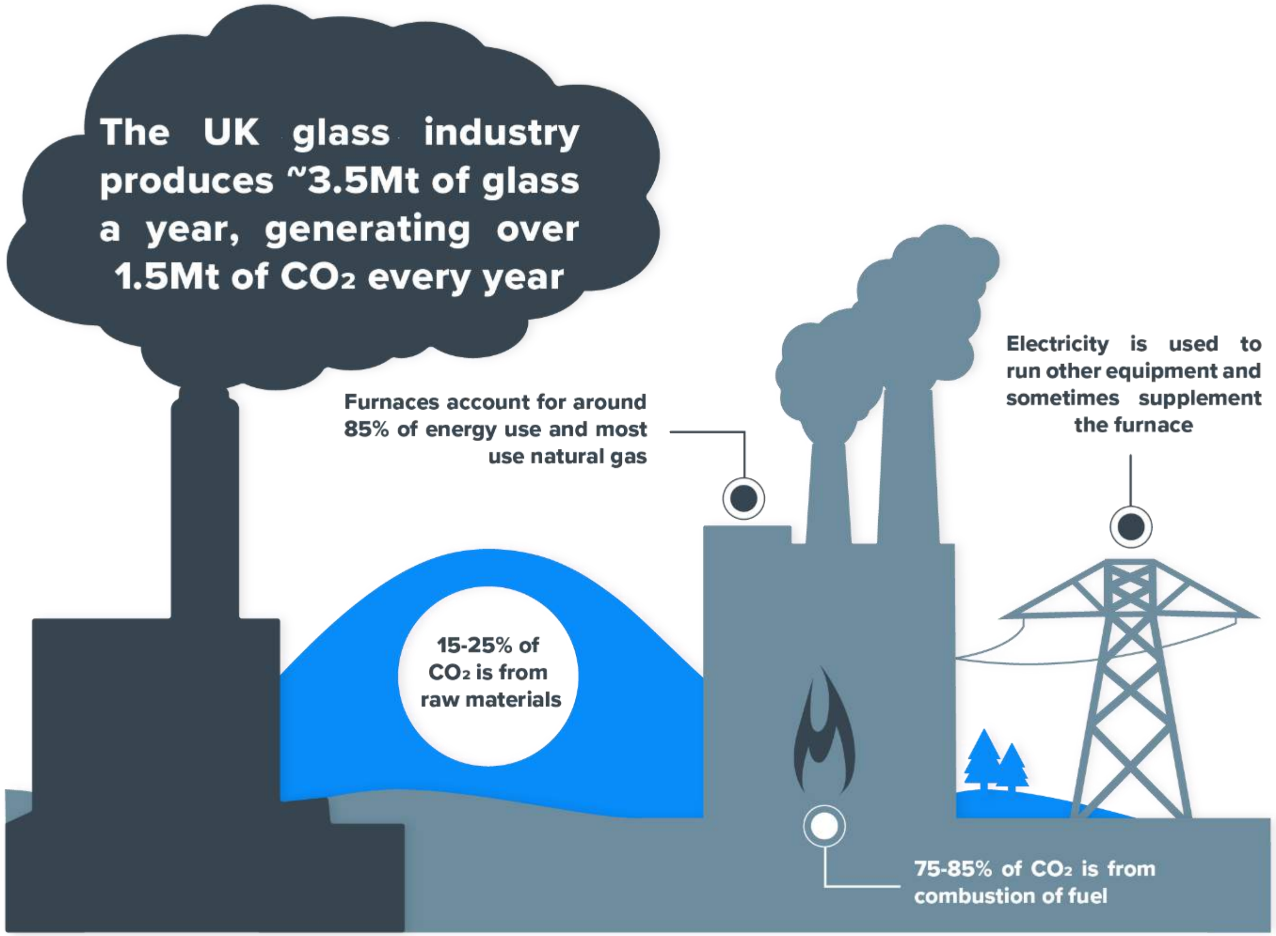
cpi

LUCIDEON

Materials Processing Institute

Innovate UK

What is the Alternative Fuels theme about?



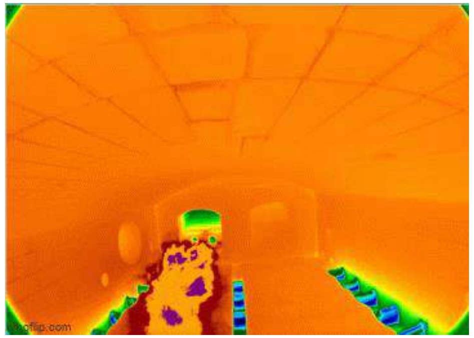
Challenges of moving away from fossil fuels:

- Similar across FIs
- Energy intensity
- Capital equipment risk
- Product quality concerns

For a rapid transition, significant confidence in the safe use of new fuels is required

Economiser 1: Aligning centre expertise

	GFL	CPI	MPI	Lucideon	Other FI
Ceramics	BCC-H2 Biofuels IFS P2 – BCC IFS P2 - Biofuels	PRO-GREEN H2	Cement 2 Zero	PRO-GREEN H2	Michelmersh Ibstock
Glass	IFS-R1P3 IFS-R1P2 EcoLowNOx Biofuels DEEP IFS P2 - Biofuels RAD-Electric				KEW (MADE)
Steel	HYDESS EcoLowNOx		H2DRI pilot Green H2 in Steel OISH Large castings		



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Economiser 1: Main activities

Glass Futures

- Upgrading 30 t/day pilot and 350kW CTB to provide capabilities for firing a large range of alternative fuels

LUCIDEON

- Upgrading firing systems for 24m tunnel kiln (heavy clay) and 1.5m^2 intermittent kiln
- Providing blends as well as 100% H_2

Materials Processing Institute

- Upgrading 2 MW Pilot reheat / heat-treat furnace to run on hydrogen.
- Electrolytic metal refining rig
- Lab-scale hydrogen furnace for refractory testing

HENRY ROYCE INSTITUTE

Sprint projects:

- Thermodynamic modelling for new refractory selection
- CFD modelling of plasma torch heating

cpi

- Signposted people to experts in CPI and external contacts in alternative fuels

Hydrogen, electricity, biofuels, by-products and waste streams as fuels, mixed fuels

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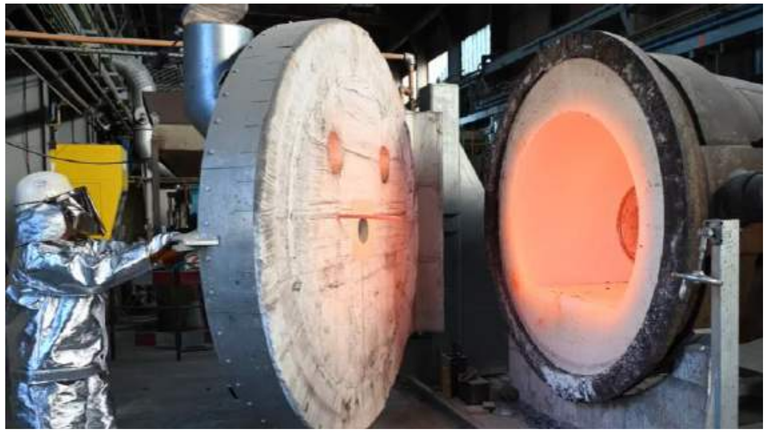
Economiser 1: Building capability

Materials Processing Institute

Electrolytic metal refining pilot rig (can mimic EAF)

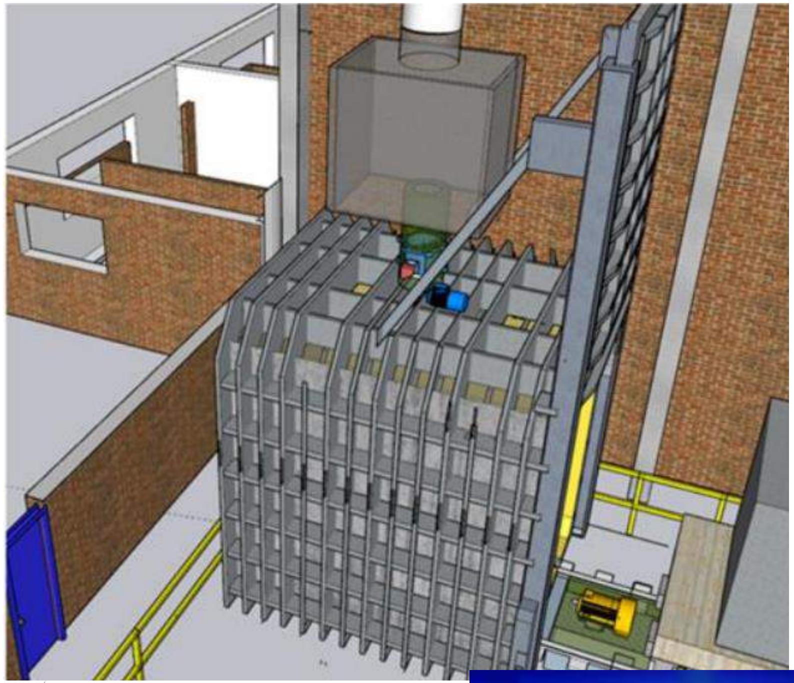


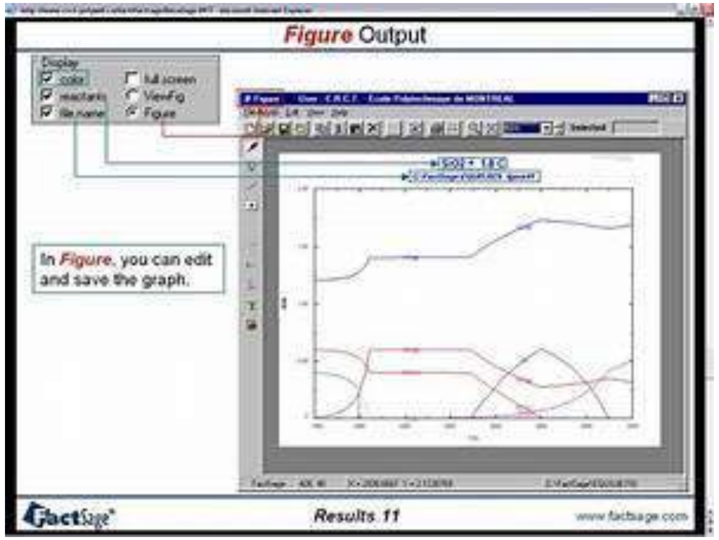
2 MW Pilot reheat / heat-treat furnace

Glass Futures

Steelwork for Lehr and Hydrogen forehearth to enhance 30tpd glass furnace facility

Economiser 1: Building capability





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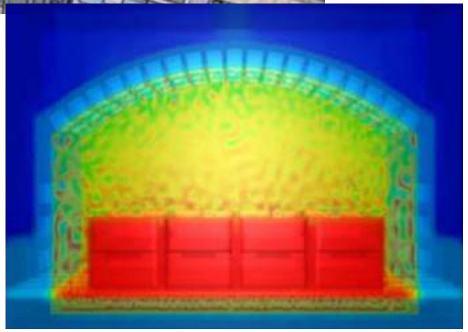
FactSage capability

Materials Processing Institute

Multi-fuel Bogie Hearth Furnace
Oct 2024



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Economiser 1: Building capability

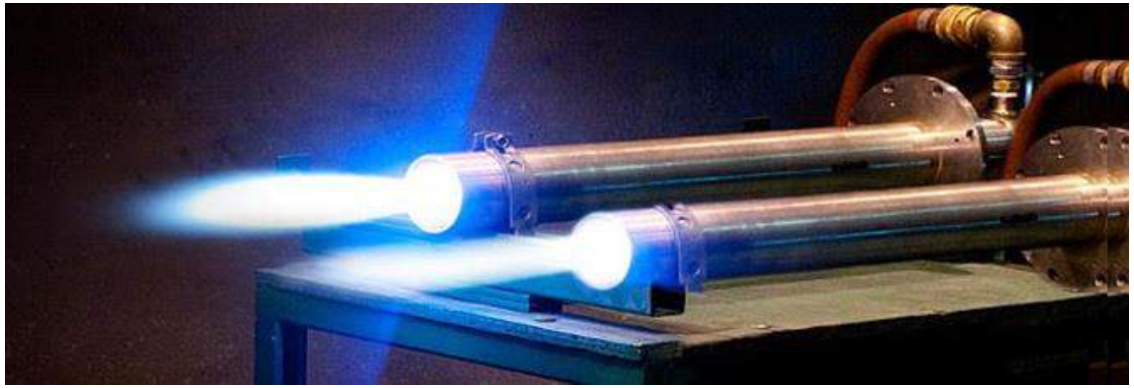
Batch research kiln fitted for 100% H2 up to 1750°C, commissioned by May 2024

LUCIDEON

Roller Kiln refit for 100% H2 Commissioning June 2024

Sprint Projects

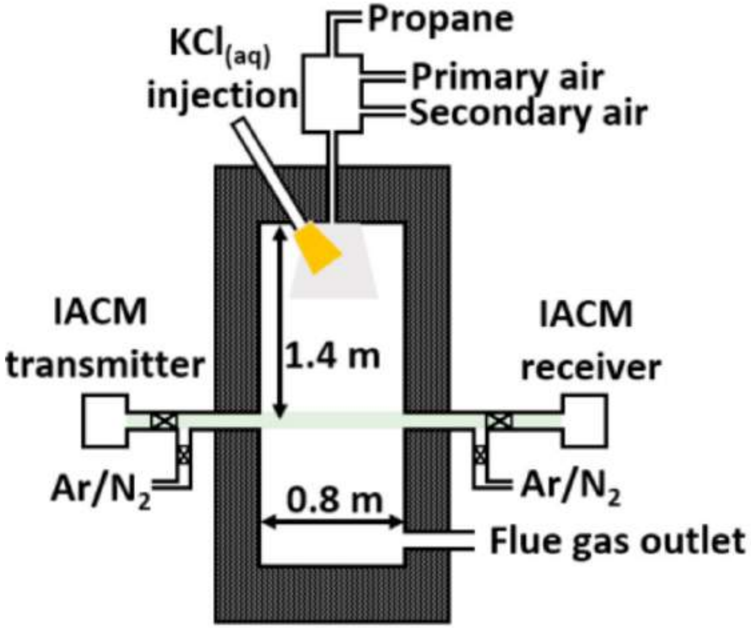
FactSage Thermodynamic modelling of potential refractory compositions for use with Hydrogen combustion.



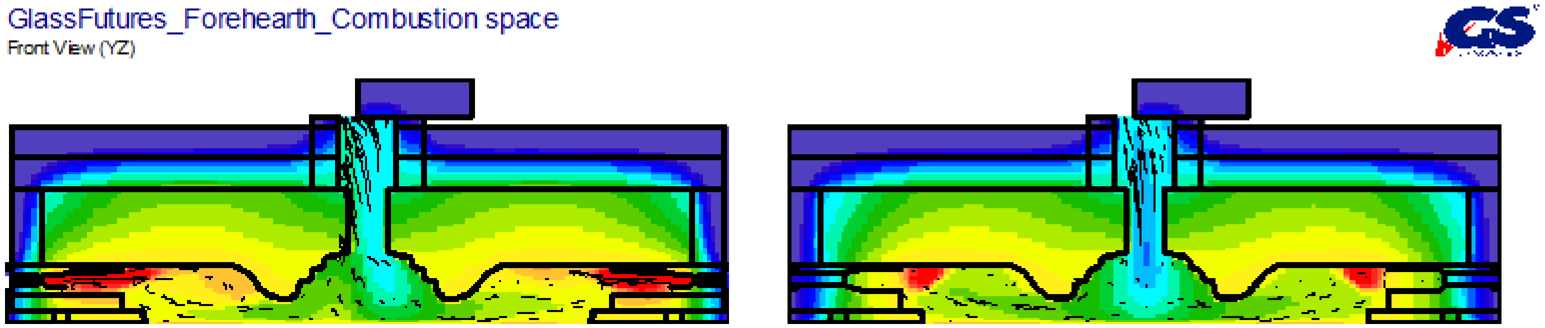
CFD modelling of plasma torches.

What is planned for Economiser 2?
WP1 Enhancing Alternative Fuels Capabilities

Lucideon: Electric Brick Kiln



GFL: High temperature salt vapour analyser

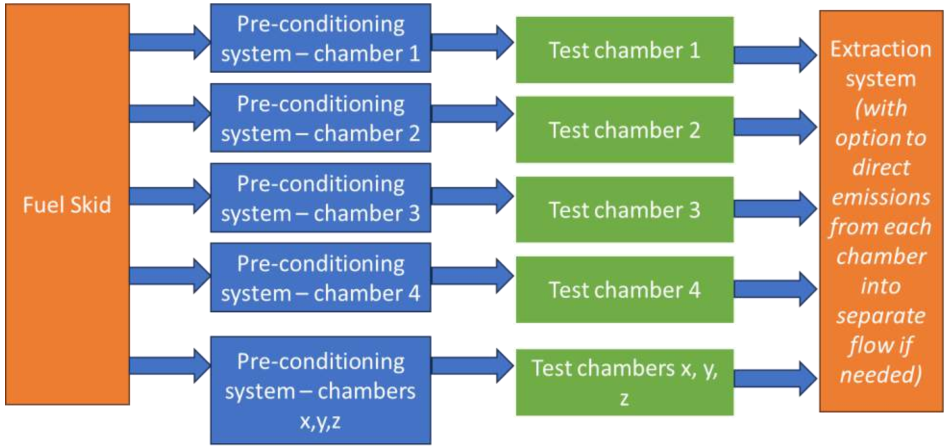


Base case - NG / Air

Case 3 - H2 / Oxy

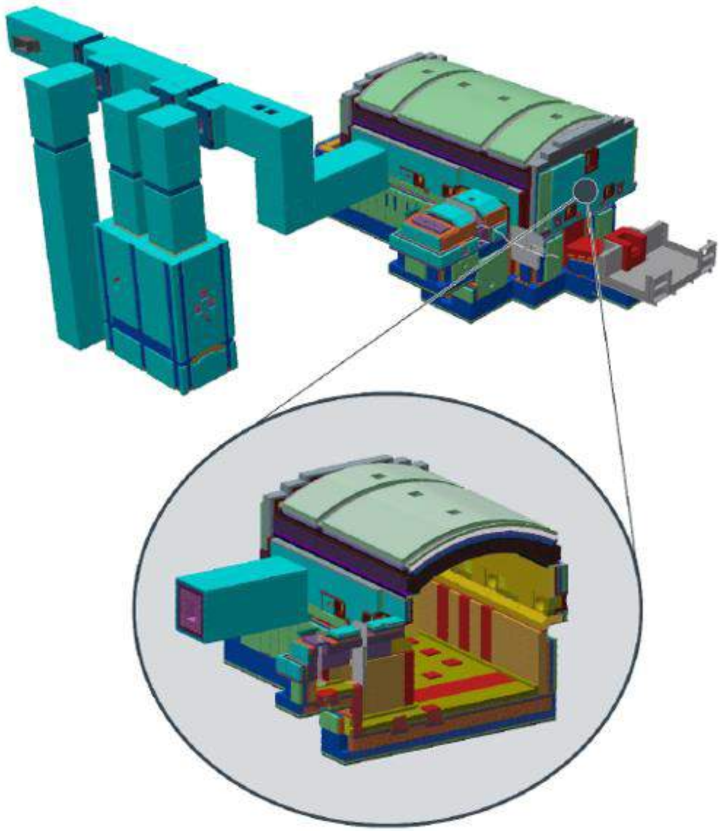
GFL: H2 Forehearth

What is planned for Economiser 2?
WP2 Refractory testing

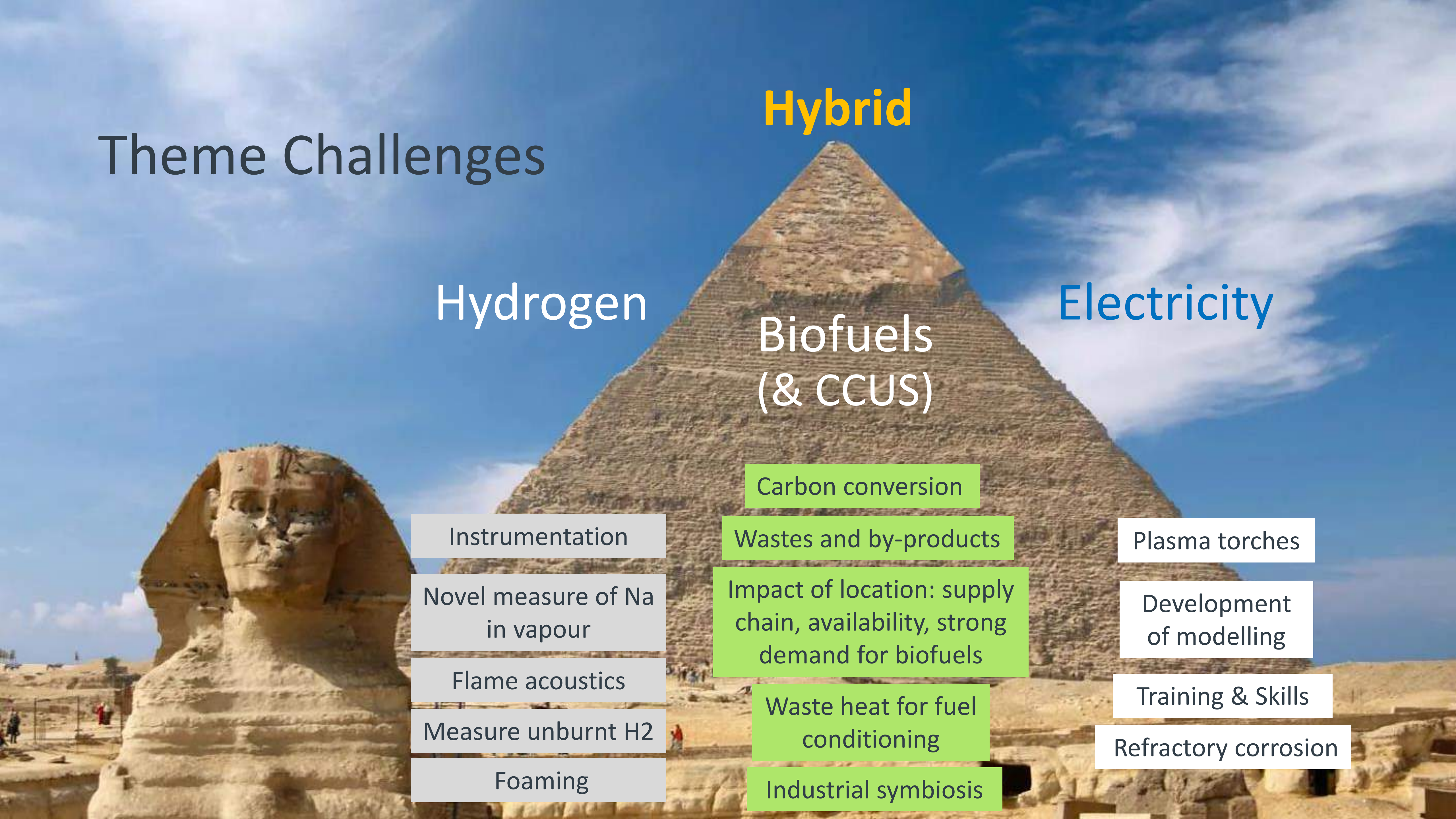


Refractory Test Bed

Refractory Test Pocket



Refractory Workshop/Laboratory



Theme Challenges

Hybrid

Hydrogen

- Instrumentation
- Novel measure of Na in vapour
- Flame acoustics
- Measure unburnt H2
- Foaming

Biofuels (& CCUS)

- Carbon conversion
- Wastes and by-products
- Impact of location: supply chain, availability, strong demand for biofuels
- Waste heat for fuel conditioning
- Industrial symbiosis

Electricity

- Plasma torches
- Development of modelling
- Training & Skills
- Refractory corrosion

Circular Economy

Dr Dominic Wales, Henry Royce Institute | 20/03/2024

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- What is the Circular Economy theme?
- EconoMISER 1 – What has been achieved in the Circular Economy Theme?
- What Circular Economy theme activities will be happening in EconoMISER 2?
- What can the theme do for you?

Circular Economy (CE) Theme

- *There is no 'final and consensus definition of circular economy'* *(Kirchherr et al., 2023)*
- Some of the common concepts:
  - The '3Rs' (*n*Rs); alternative to the linear economy model; addressing material scarcity and security; a regenerative system
- Within the theme group we set out the following scope for the theme:
  - Identify the current position of the foundation industries against the theme of the Circular Economy.
  - Ensure the EconoMISER project activities are delivered and reassess the position once the project has been completed.
  - Develop a long-term (10 year) plan for the circular economy theme to support the development plan of FISC consortium. This will identify actions that the UK-FIs can take to improve their resource efficiencies whilst aligning resource streams, to move towards the goal of a Circular Economy.

Kirchherr *et al., Resources, Conservation & Recycling*, **194**, (2023), 107001

Circular Economy (CE) Theme

- Circularity of recyclable polymers
- Sustainability and circularity of packaging
- Waste reduction within ceramics and cementitious materials processes
- Material reuse for fabrication of geopolymer cements
- Circular Economy Centre for metals and metal adjacent materials.
- Hydrometallurgy for recovery of metals from batteries
- Process monitoring and sensor/analytical capabilities to assess glass throughout the lifecycle

EconoMISER 1: CE – CapEx

Partner	Example CE CapEX
Henry Royce Institute (HRI) (located at various institutions)	Respirometers; DEECOM unit; polymer mill and more…
Glass Futures	Forehearth; cullet collection, handling and storage equipment and more…
Materials Processing Institute (MPI)	Upgrade of hydrometallurgical equipment for hydrogen recovery; processing equipment (grinders, ball mills, etc.) and more…
Centre for Process Innovation (CPI)	Upgraded sustainable polymer scale-up capabilities (especially packaging) and more…
Lucideon	Capabilities for scale-up of geopolymer manufacture from by-products/waste materials from other industries, and more…

For more information, please contact me: dominic.wales@manchester.ac.uk

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EconoMISER 1: CE – Sprint projects

- Three Circular Economy Sprint projects in EconoMISER1
  - Materials (Industries): ferrous metal, plastic/polymer & glass.
  - Collaboration between the FISC partners
- *Henry Royce Institute (HRI):* Literature study focussed on chemical recycling of a polymer
- *HRI & Centre for Process Innovation (CPI):* Literature search & preliminary economic feasibility study into recovery and regeneration of an acid
- *HRI & Glass Futures (GF):* Experimental study into recovery of a glass dust

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Sprint project case study

- Literature search & preliminary economic feasibility study into recovery of an acid
- This industry had surveyed the literature back in the early 00's
- At the time that there wasn't enough of a driver to recover and regenerate the acid as:
    - Fresh acid was cheap
    - Acid supply was secure
    - Acid waste removal costs were cheap
- Fast forward 20+ years (and after the pandemic):
    - Acid supply is far less secure
    - Acid waste removal costs have increased
    - More awareness and impetus for circularity
- Literature study reviewed acid recycling technologies against the client's requirements and constraints – a single innovative technique that will achieve acid recycling
    - No new innovative acid recycling techniques since 00's
    - But those technologies are more developed
    - We determined that a combination of technologies would be required
- Assessed the feasibility of combined technologies through some preliminary economic feasibility calculations
- Our findings have shown that with the current supply scarcity and increased waste removal costs that implementation of acid recycling/regeneration technologies needs to be revisited

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EconoMISER 1: CE – 'Big Ideas'

- Composites recycling – combining shared knowledge on composites recycling across all the partner organisations.

- Resource mapping – mapping materials streams and supply chains, whilst building on existing knowledge, to identify opportunities.

- Building demonstrator – reuse and recycling of building materials on-site

- Paper recycling centre - paper recyclability testing to *Cepi* standards. To enable testing and approval of new packaging items as suitable for incorporation into paper recycling streams.

EconoMISER 2: Circular Economy

- WP3:Paper Innovation: Equipment for recyclability standard testing, set-up for gaining necessary accreditation. - CapEx equipment for paper recyclability testing to *Cepi* standards. This will enable testing and approval for new packaging items as suitable for incorporation into paper recycling streams.

- WP4:Multipurpose plastics recycling: Design and build of multivessel plastics re-processing rig for purifying product feedstocks. Turn end of life multicomponent plastics into chemical feedstocks.

- WP9:Chemical Feedstocks Replacement: Specification, design and build of fully automated rheology measurement platform. Qualify and validate recycled chemical ingredients - rheology is key product attribute, significantly affected by nature and quality of replacement sustainably sourced feedstocks.

FISC: Circular Economy Theme

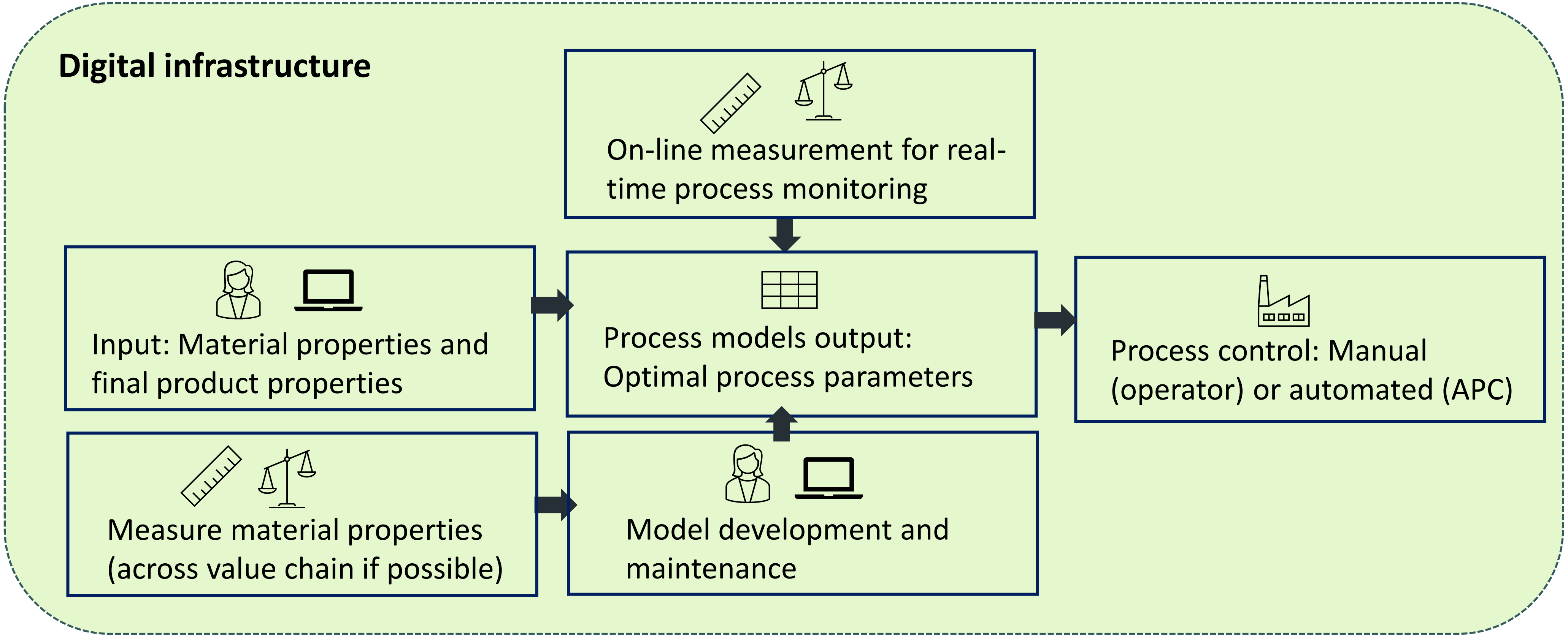
- An open challenge to the audience:
  - What else can we do for you?
  - How will you engage with us?
  - We want more industrial collaboration – we want to support the Foundation Industries!
  - Contact me: dominic.wales@manchester.ac.uk

Digital Theme Update

Katharina Roettger | 20 March 2024

katharina.Roettger@uk-cpi.com

Digital Theme: Objectives



Implement and demonstrate control systems and digital technologies that improve process efficiency and reduce emissions.

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Capability build

Control & monitoring hub connecting to all areas of plant: Batch house, furnace, forehearth, abatement, lehr(s), packaging & utilities.

Mechanistic Simulation to support manufacturing & process design

On-line measurement for real-time process monitoring

Input: Material properties and final product properties

Process models output: Optimal process parameters

Process control: Manual (operator) or automated (APC)

Measure material properties (across value chain if possible)

Model development and maintenance

Collaborative Robotics demonstrator

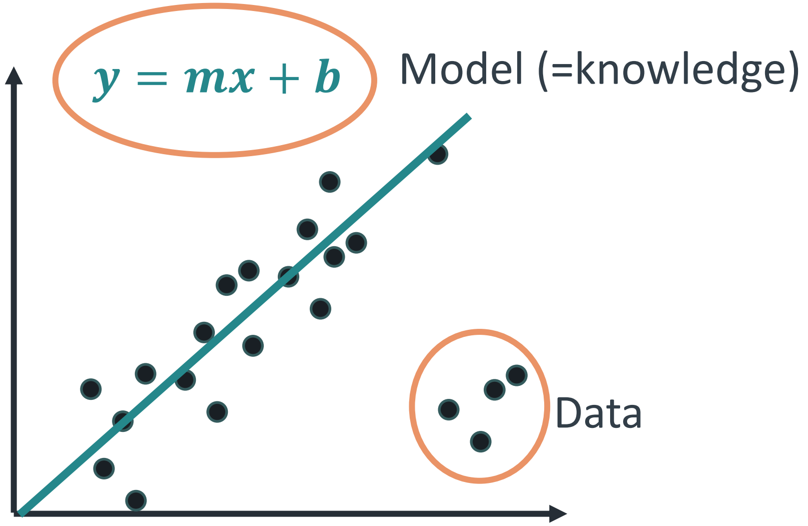
Software & hardware for data analytics & process modelling

Demo data curation tools (e.g. ELN, secure storage, QR codes for samples)

- CPI
- Glass Futures
- Henry Royce

Economiser 2: Federated Learning to Enhance Process Control and Optimisation

Federated Learning: Method to **share knowledge without sharing data**



Establish a Federated Learning Testbed to common hardware installations by leading technology provider(s) paired with open interfaces and a range of sensors to run comparative equipment trials/proof-of-concept work outside of live plants.

Demonstrators through Economiser 2: Furnace modelling (with WP6); plastics recycling (with WP4); next generation alloy development (with WP7)

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Capability build

Control & monitoring hub connecting to all areas of plant: Batch house, furnace, forehearth, abatement, lehr(s), packaging & utilities.

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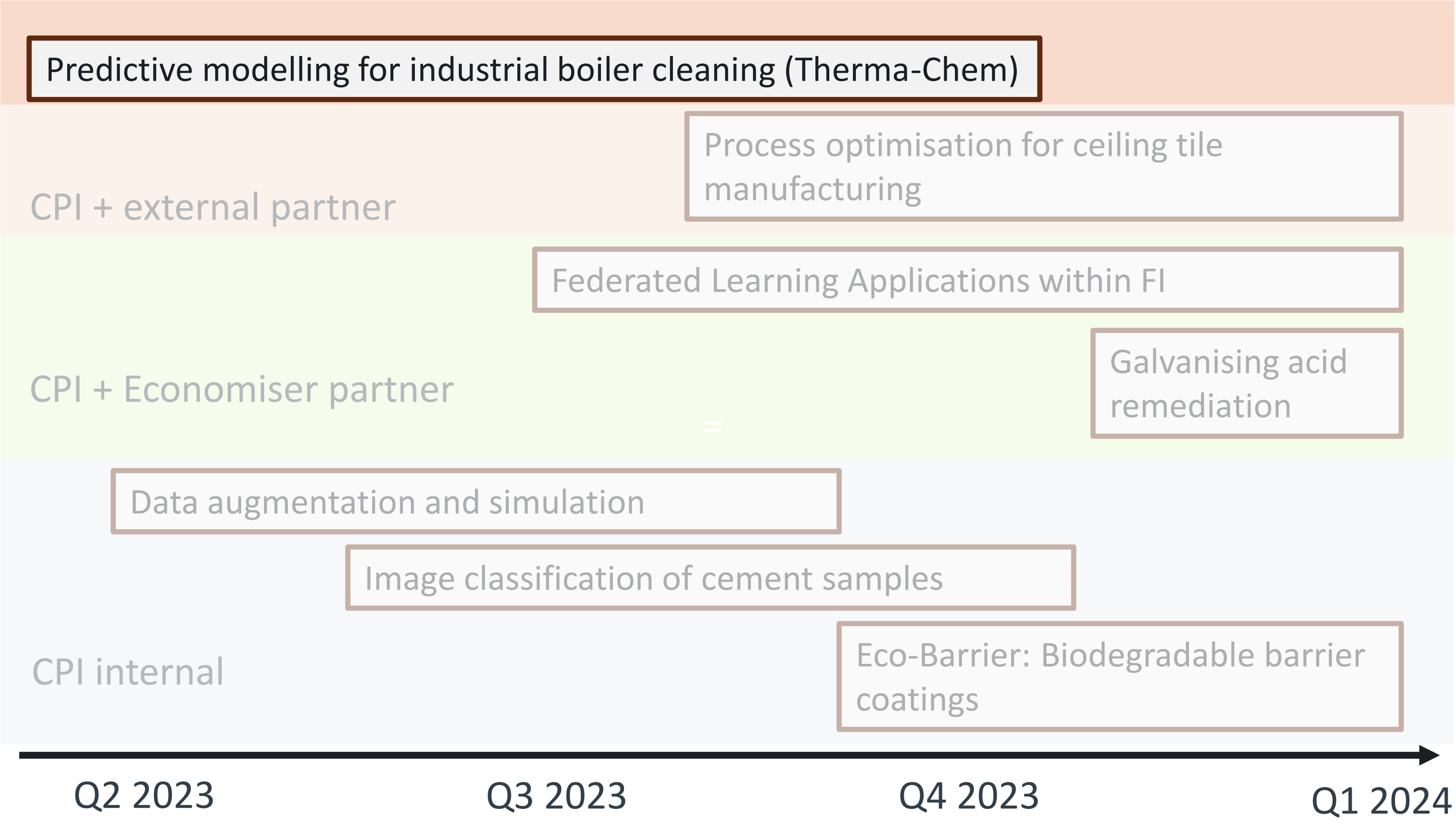
Software & hardware for data analytics & process modelling

Demo data curation tools (e.g. ELN, secure storage, QR codes for samples)

- CPI
- Glass Futures
- Henry Royce
- E2: Federated Learning

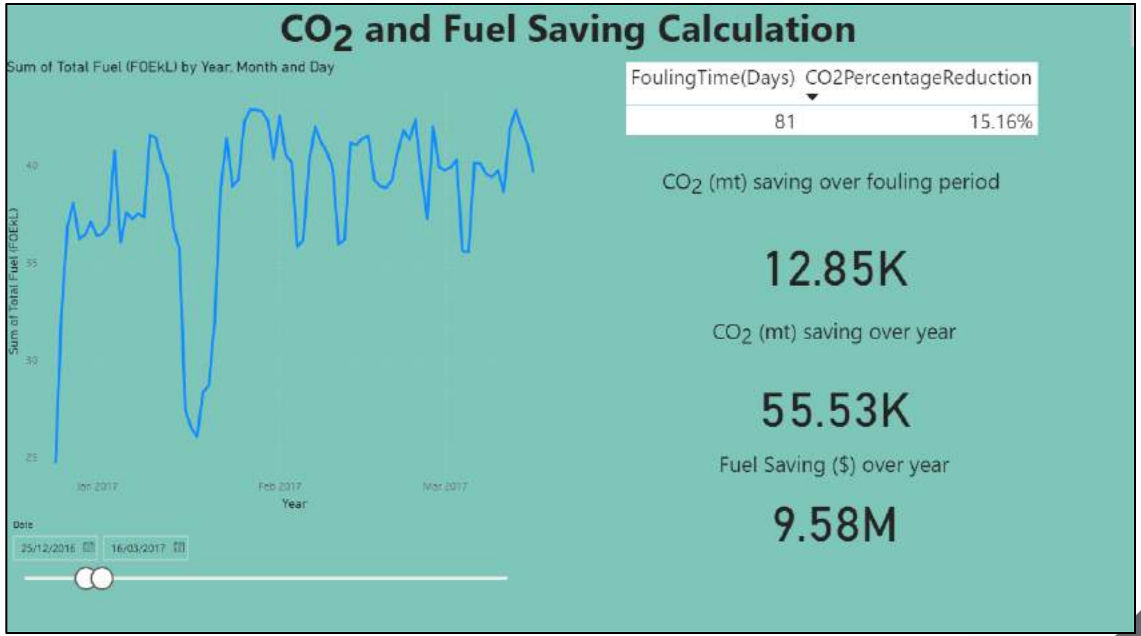
Digital & Process Optimisation Theme Case Studies



Digital and Process Optimisation Case Study: Industrial Boiler Cleaning

- Automation enables reduced time processing data from customers
- Quicker visualisation of customer data
- Additional analytics of customer data
- Proof-of-concept predictive model for predictive maintenance

Dashboard with fuel, CO2 and cost savings displayed:



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Future Use Cases

If you had a magic wand and you could change three things about the way you monitor and control your process, what would you do?

- What data collection systems do you have in place already?
- Are there data which are currently unused?

It doesn't need to be 'big data', small data sets can be useful too.

Please get in touch with any of the Economiser partners if you are interested in trialling the digital tools!

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Process Optimisation Theme

Dr Cathryn Hickey | 20 March 2024

Henry Royce Institute · Glass Futures · cpi · Lucideon · Materials Processing Institute

Alternative fuels

Circular economy, feedstock, recycling and reuse

Digital control and sensors

Process optimisation

Improving the process efficiency and reducing the energy associated with heating material reduces material and energy input directly affecting profitability and the impact of carbon. Work will include process design, better furnaces and heat/material management.

Sustainable materials development

Process Optimisation

Systematic Process measurements and analysis to create low-cost process optimisation and consequent waste and energy reduction

Individual confidential company learning on their process

Alongside sector learnings on optimisation

Short timescale – existing system optimisation giving long term benefit

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Theme objectives

- New capabilities within the consortium to understand and improve process optimisation within foundation industries

Glass futures

Container forming and control infrastructure

CPI

Developing process optimisation case studies

HRI

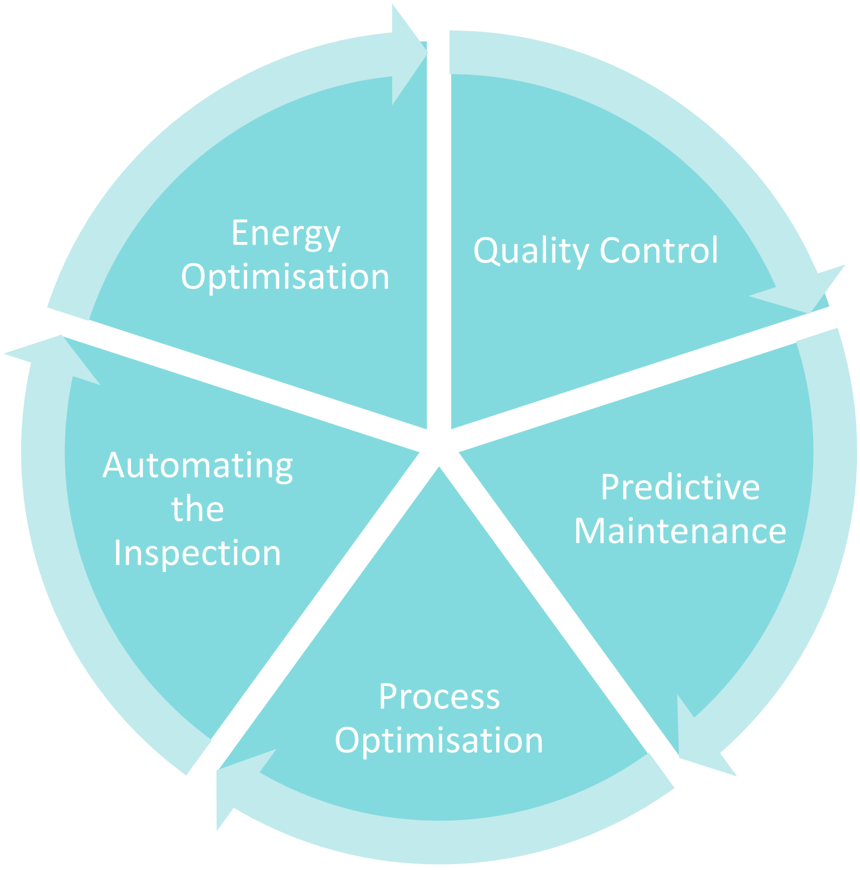
Low energy ceramic processing techniques

Lucideon

Time-series machine learning infrastructure and capabilities

Data Science for Process Optimisation

How it facilitates the Process?



Increase overall Efficiency

Improve product quality

Reduce cost and wastages

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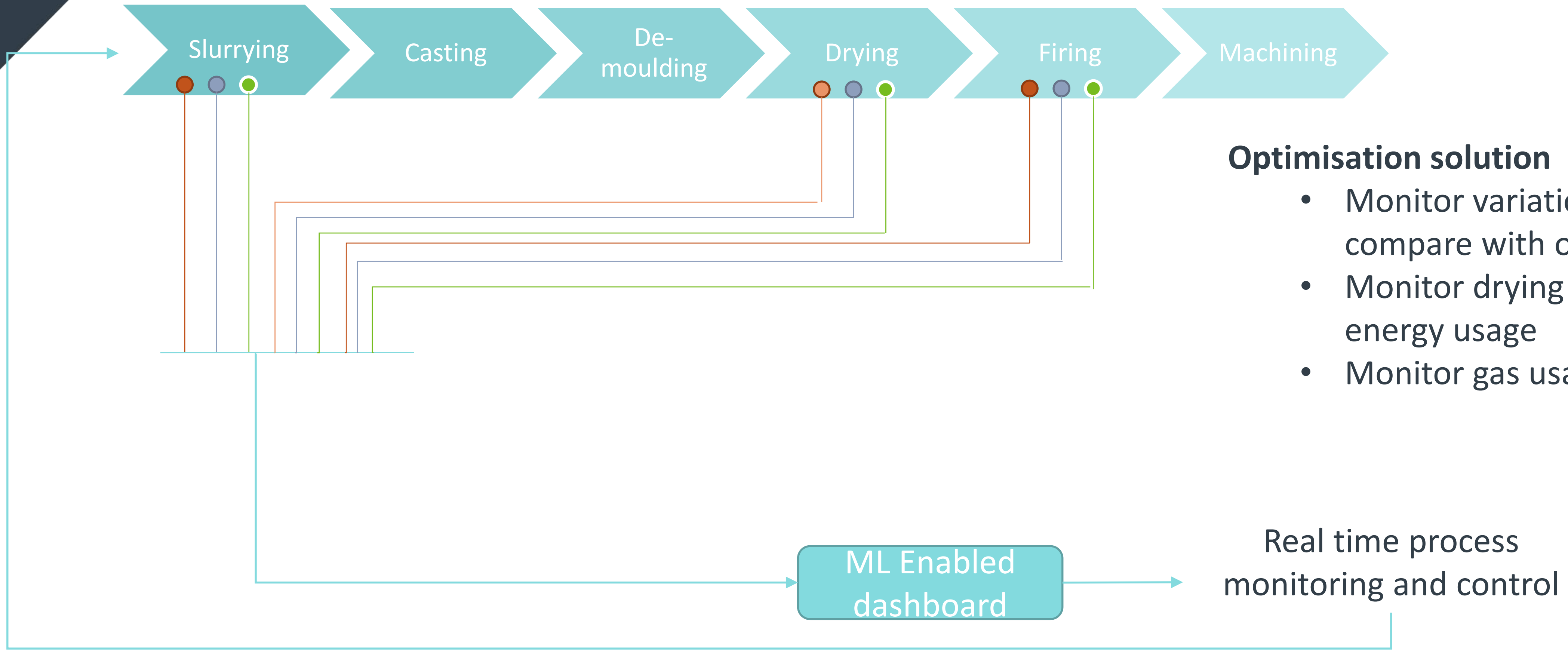
Refractories manufacturer

Overview of the process



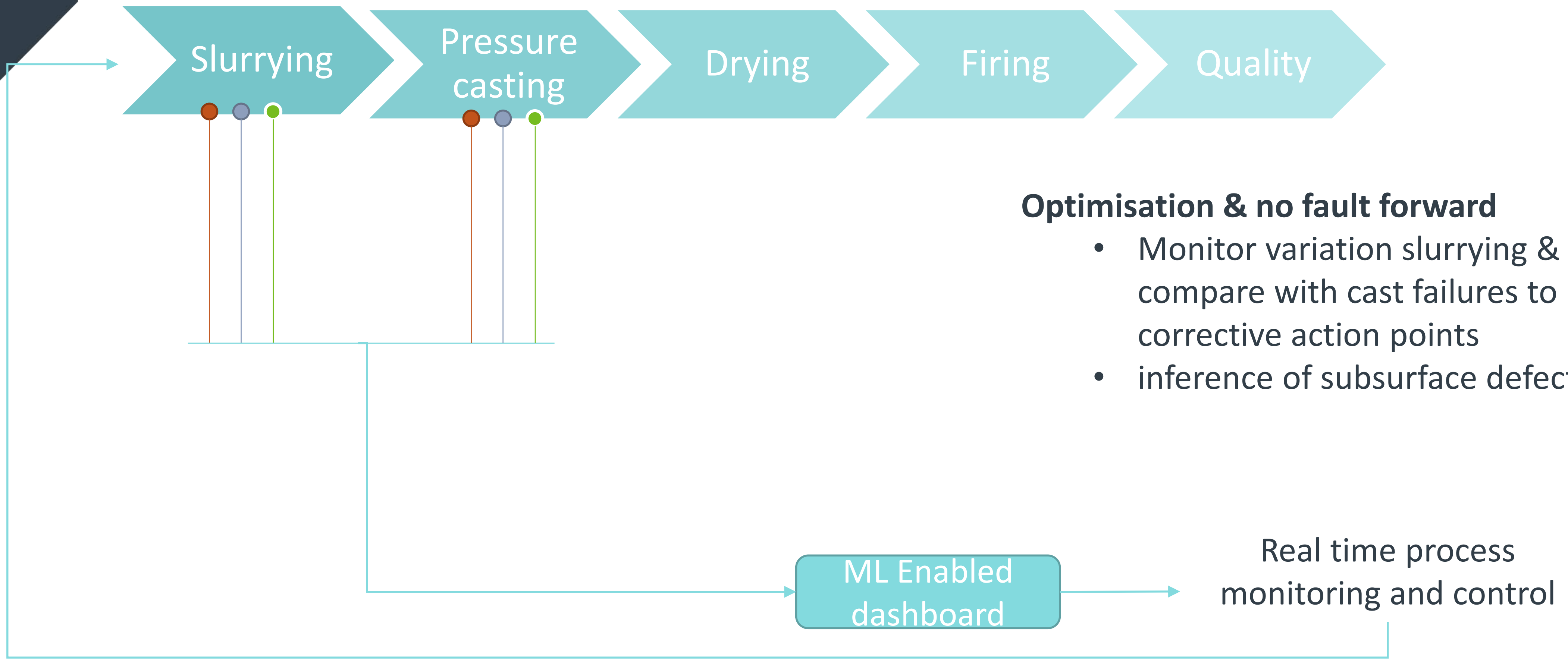
Optimisation solution

- Monitor variation slurrying & compare with output KPIs
- Monitor drying to optimise energy usage
- Monitor gas usage variation

Real-time feedback loop

Hospitality ware manufacturer

Overview of the process



Optimisation & no fault forward

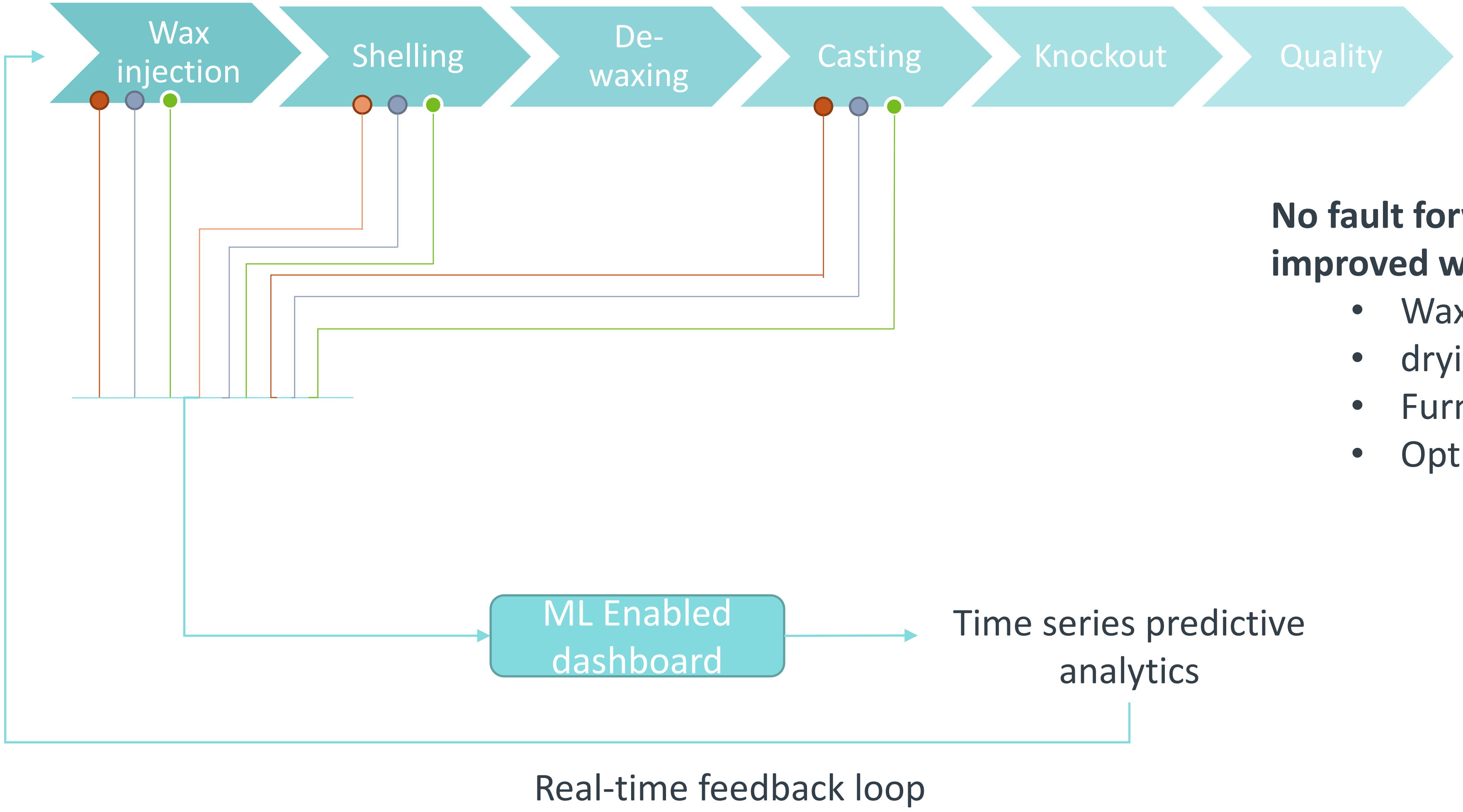
- Monitor variation slurrying & compare with cast failures to look at corrective action points
- inference of subsurface defects

Real-time feedback loop

Confidential. Commercial in confidence.

Cast metals manufacturer

Overview of the process



No fault forward, process control & improved ways of working

- Wax process
- drying process
- Furnace efficiency
- Optimise workflows

Main Themes

Some main themes emerged relating to heat management:

- The efficient use of furnaces was the main common pain point highlighted to us

- Variability in the manufacturing process causing failures that only appear after the furnace

- Have furnaces running for days at a time sometimes empty for hrs at a time

- One of their main pain points again is around ceramics-the shelling part of their process where controlling drying is key

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Improved capabilities

- Cross industry discussion has increased understanding of FI process optimisations challenges
- Identified especially heat management and furnace operations are common
- Developing case studies to demonstrate potential gains from collection and analysis of time series data
- Investigating ways to retain job intuition through sensors, data collection and analysis
- Retention of skills and knowledge - considering innovative ways to do this for future

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Economiser 2.0 Furnace modelling

- A key learning from conversations across all Foundation industries is the need to optimise heating processes and furnace operations

- Aim is to understand how we can model, optimise and simulate furnace parameters offline and transfer that learning to manufacturing situations across FI

- Increased sensors involving, thermal imaging, HD cameras and online monitoring of the heating process.

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EconoMISER
Sustainable Materials

Christopher Smith CEng MIMechE
Theme Lead: Sustainable Materials
Materials Processing Institute

Foundation Industries Sustainability Consortium

What is a Sustainable Material?

- Anyone?

What is a Sustainable Material?

Sustainable materials are materials used throughout our consumer and industrial economy that can be produced in required volumes without depleting non-renewable resources and without disrupting the established steady-state equilibrium of the environment and key natural resource systems.

Such materials vary enormously and **may** range from bio-based polymers, or highly recyclable materials such as glass or metals that can be reprocessed an indefinite number of times without requiring additional mineral resources.
(Rutgers University, http://sustain.rutgers.edu/what_are_sustainable_materials)

Sustainable materials may be sourced from low environmental impact or renewable resources, be more durable with a longer lifecycle, have a smaller footprint to manufacture or use, or be easier to break down at end of life. Some can even be human-made materials, designed to help preserve natural resources.
3M (https://futures.3m.com/sustainable-materials#:~:text=Sustainable%20materials%20may%20be%20sourced,to%20help%20preserve%20natural%20resources.)

What is a Sustainable Material?

Can we express it as a goal?

- Reduce environmental impact
- Reduce use of finite resources
- Increase use of secondary raw materials
- Sustainable/renewable energy
- Bio-degradable (where appropriate)
- Designed for repair / reuse / second life / recovery & recycling

- Performance enhanced product

To be truly sustainable we need to measure, assess and prove it, from:

- Raw materials (primary & secondary) > manufacturing > in use > end of life

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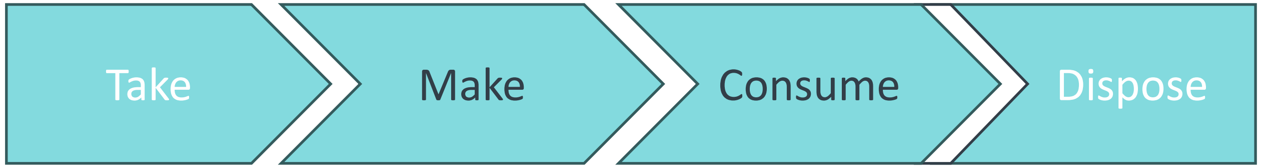
What is a Sustainable Material?



Traditional linear economy, focus on:

- production efficiency
- Minimum resources used in production (maximum sale value/returns)
- Focused: Product performance optimisation

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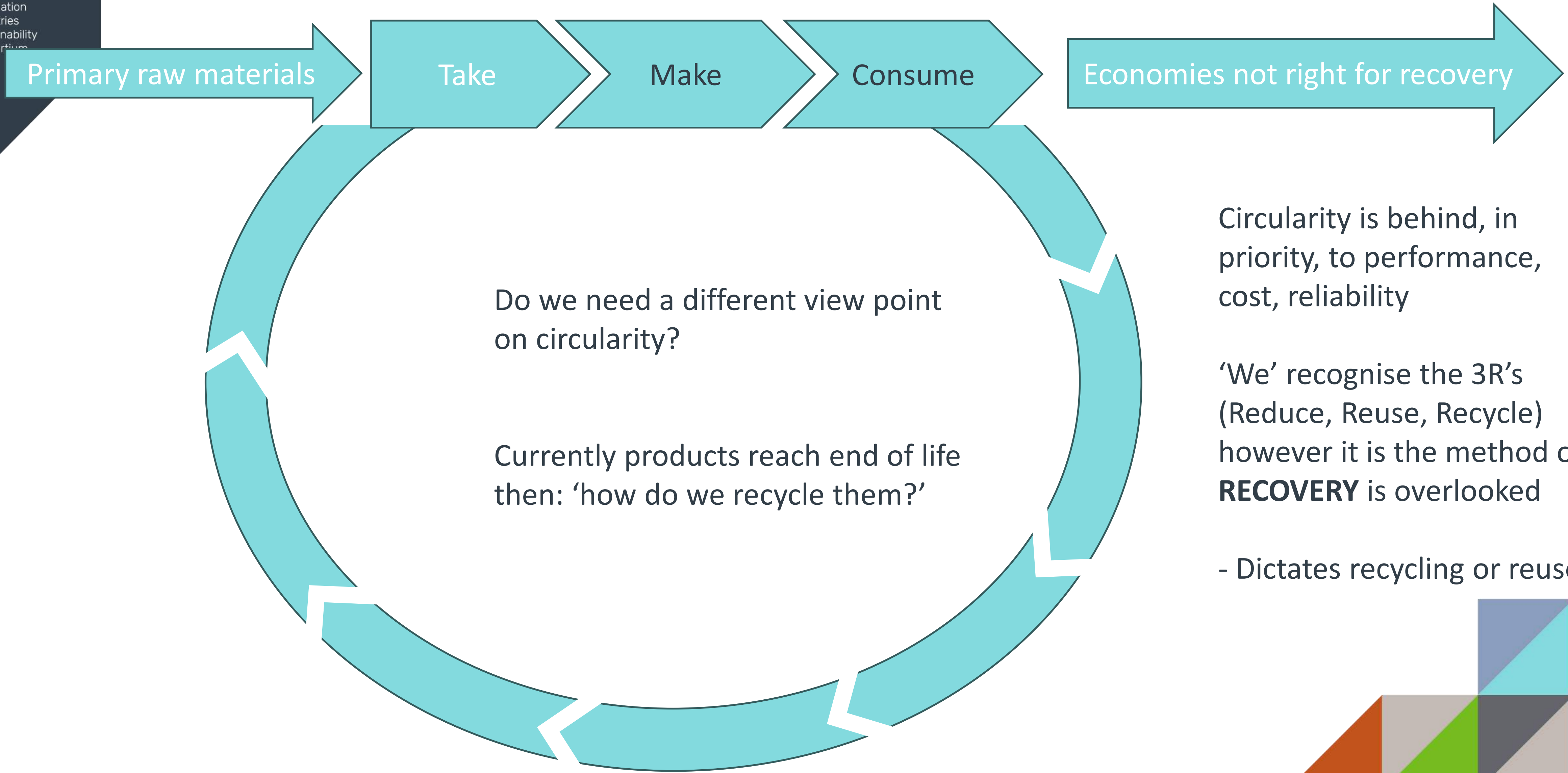
What is a Sustainable Material?



Do we need a different view point on circularity?

Currently products reach end of life then: ‘how do we recycle them?’

Circularity is behind, in priority, to performance, cost, reliability

‘We’ recognise the 3R’s (Reduce, Reuse, Recycle) however it is the method of **RECOVERY** is overlooked

- Dictates recycling or reuse

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What is a Sustainable Material?

Primary raw materials

Economies not right for recovery

When the circularity is prioritised we will have sustainable materials:

BUT, what do we need to do to get there?

- Design for it
- Do we need to re-think production focus from the linear economy
- Understand sustainable economy as well as sustainable materials
    - Eg Materials passport and value of data

Economiser 1.0 Investments

4 work streams were identified within Sustainable Materials submission, each lead by a different consortium partner, investment totalled £2.9M CAPEX:

- MPI: Fusion reactor and geopolymer materials development infrastructure
- Lucideon: enhanced sustainable ceramics materials manufacturing/processing capabilities
- CPI: Pilot scale (1-10 kg) chemical processing capabilities, sustainable polymers, advanced materials, organic materials (new monomers, glues, additives)
- Royce: investment to accelerate development of low-carbon cements and geopolymers

MPI: Advanced Materials Development Centre

Economiser funds were used to enhance the AMDC with, (delivery ongoing):

- Press Forge
  - 50-ton
  - Open die forge
  - Working area: 380 x 300 mm
- Vacuum Brazing Furnace (Ipsen 324)
  - Operating temperature = 1200 ºC
  - Working area: 570 x 300 x 900 mm
  - Max Operating Vacuum: 10^{-5} mbar
  - Argon Partial Pressure
  - Argon Quench Pressure: 0.9 bar
- Small reheat furnace
  - 1300 ºC, 36 litre capacity

(In black Economiser 1.0 purchases)

(In blue funded from elsewhere)

- Bogie Hearth Furnace (Caltherm)
  - Operating temperature 1200 ºC
  - Working area: 650 mm^3
- Quench tank: 950 mm^3
- Reversing Rolling Mill (Stanat 625)
  - Separation force: 113,500 kg
  - Max length: 2 m
  - Mill power: 29 kW
  - Heated rolls (260 ºC) capable of accepting material up to 1260 ºC
  - 200 mm wide rolls

MPI Geopolymers Materials Development

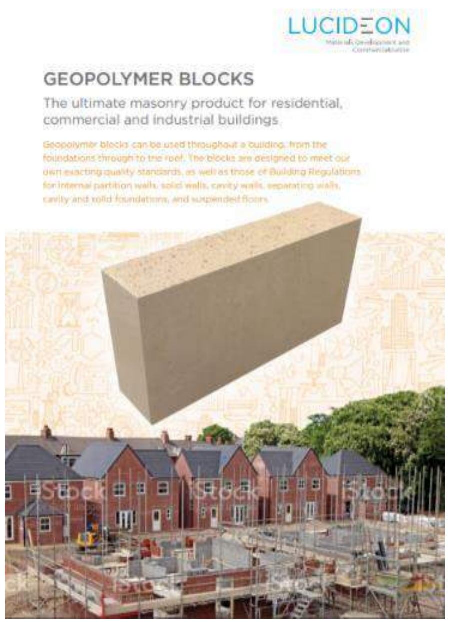
- Accelerated ageing chambers
  - Volume: 56 litres
  - Temperature range: -50 to + 180 C
  - Relative humidity range: 10 to 98 %
  - Full programmable/cyclable

Accelerate aging chambers

- CHNS elemental analyser,
  - Carbon, hydrogen, nitrogen, sulphur combustion products analysed by gas chromatography
- Upgrades to:
  - SEM, enhance imaging conditions and characterisation ability
  - XRD, cobalt anode to characterise different materials
  - TGA, increase temperature characterisation range
- Preparation/characterisation equipment
  - Plastometers, 3D mixer, Charpy, bead maker, planetary ball mill

Lucideon: EconoMiser Geopolymer Facility

- Builds on ten years' experience of developing geopolymers (alkali activated cements) for industrial applications, such as construction products and waste encapsulation
- Focus: Provide Scalability and consistency in geopolymer cement developments
- Capabilities cover
  - Geopolymer formulation for different forms and functions
  - Increasing process scale from laboratory to demonstration levels
  - Characterising product properties and durability against acceptance criteria and standard



Lucideon: EconoMiser Geopolymer Facility

- Formulation and Scale-up
  - Up to 5 litres (lab scale for initial evaluation)
  - Up to 50 litres (first stage scale up, and practical demonstration of some applications)
  - Up to 1000 litres (demonstration of practicality before commercial scale up)

- Upgrading and expanding facilities: supported by Lucideon and AMRICC facilities

- Range of mixing methods: Stirring, acoustic, forces action, paddle

- Support equipment: weighing, handling, cleaning, chemical storage

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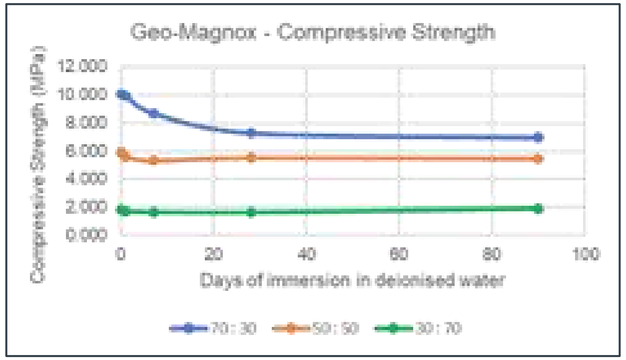
Lucideon: EconoMiser Geopolymer Facility



Strength vs immersion time

Testing and Characterisation

- Powders and Precursors:
  - AMRICC – Particle size and shape, TGA, DCS
  - Lucideon – Chemical analysis
- Slurries: rheology, pH, temperature changes, total dissolved solids
- Cements: Slumping, setting, shrinkage, strength, macro and microstructures, thermal conductivity
- Compatibility and aging: Chloride diffusion, resistivity, leach testing, strength changes

Macrostructure

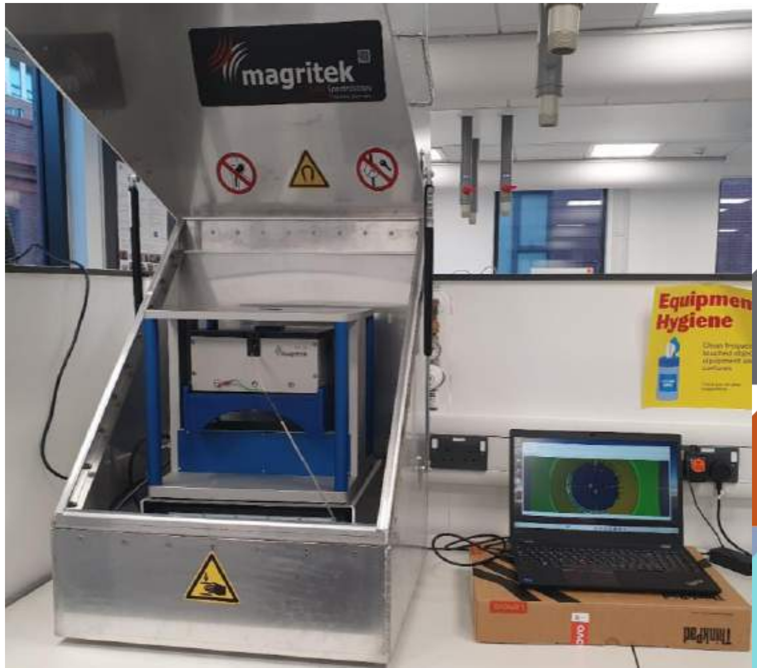
Microstructure

Royce: investment to accelerate development of low-carbon cements and geopolymers

University of Sheffield

- Dynamic Vapour Sorption (DVS) unit
  - Gravimetric technique to measure the mass of a sample as it changes due to temperature or humidity

- Unilateral Nuclear Magnetic Resonance Relaxometry (NMR) Instrument
  - Form of radio frequency spectroscopy
  - Measure homogeneity of sample, cross-link density,
  - to support quality control investigation, Equipment currently being installed



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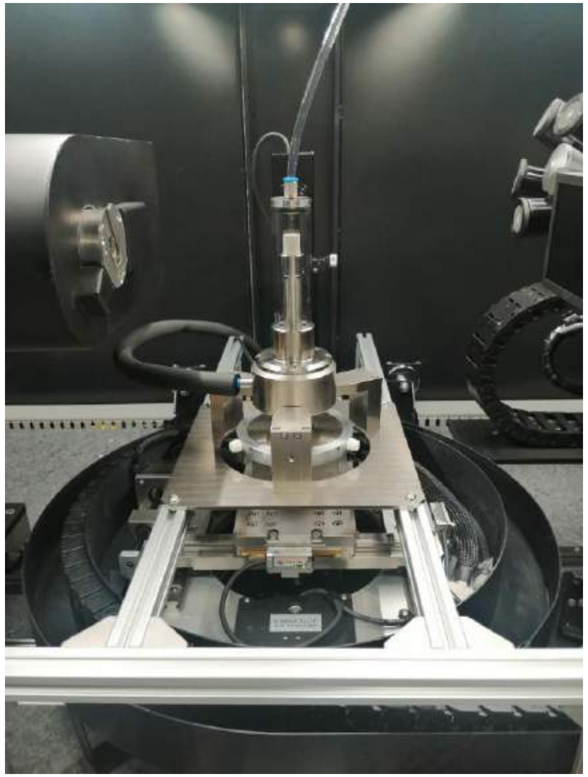
Royce: investment to accelerate development of low-carbon cements and geopolymers

University of Leeds



- XCT In-situ environmental
  - X-ray Computed Tomography,
  - Produce 3-D computer model of sample, contrast between different components is based on X-ray absorption, and is typically a function of elemental composition and density
  - 3D surface measurement
- Retsch PM GrindControl system
  - Monitoring and recording system for ball mill

CPI: Pilot scale (1-10 kg) chemical processing capabilities, sustainable polymers, advanced materials, organic materials (new monomers, glues, additives)

Synthesis, polymerization, depolymerization, catalysis, leaching etc.

- 10L Hastelloy steel reactor – jacketed for heating to approx. 225 ˚C, pressure rated, stirred, glass distillation system

Polymer processing, blending, nano/micro powder addition, other additive addition, pelletised masterbatching, film-formation

- Twin and single screw extruders –
  - Twin screw typically used for master batc blending, additive addition.
  - Single typically used for scale up, better control in film formation etc.

CPI: Pilot scale (1-10 kg) chemical processing capabilities, sustainable polymers, advanced materials, organic materials (new monomers, glues, additives)

Characterisation

- High temperature gel permeation chromatography (GPC)
- Molecular weight and polydispersity on more traditional acrylate, acrylamide, styrenic type polymers as well as trickier engineering polymers such as polyolefins. Light scattering, viscometry and concentration detectors

High temp GPC

- Melt rheometer – understanding how formulations/polymers flow under various shear/temperature environments
- FT-IR microscope – mapping chemical functionality across substrates/surfaces
- Acoustic microscope – detection of crack formation, voids, adhesive failures and other topography features

within materials e.g. fiber composites, laminar structures etc.

Economiser Sprints

- 2 x projects completed
- 1 x project live
- 2 x under development

EconoMiser 2.0: Sustainable Materials

- Alloy development centre, streamlined cross-FISC driven by AI, bounded by existing manufacturing capability, to sustainably develop the next generation alloys

- Develop testing/development capability facilitating the commercialisation of new, low carbon cements

- Chemical feedstock replacements - establish fully automated rheology measurement platform, enhancing current automated-chemical formulation labs to trial novel ingredients derived from sustainable feedstocks (CO2/biomass/recycled plastics)

FISC – What Else Can We Do To Support Sustainable Materials?

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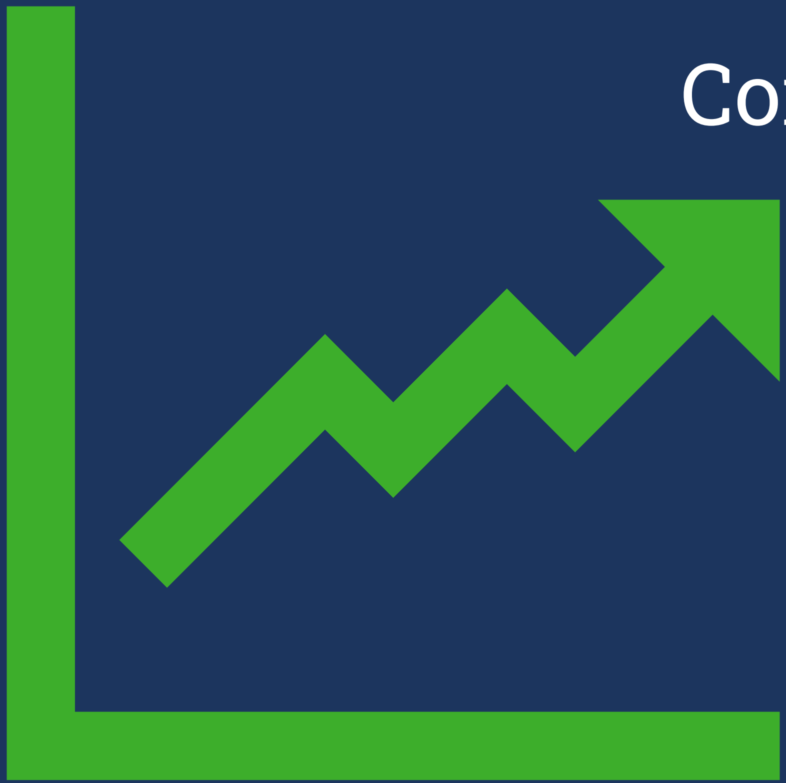
Foundation Industries Ventures

Foundation Industry Strategy Workshop

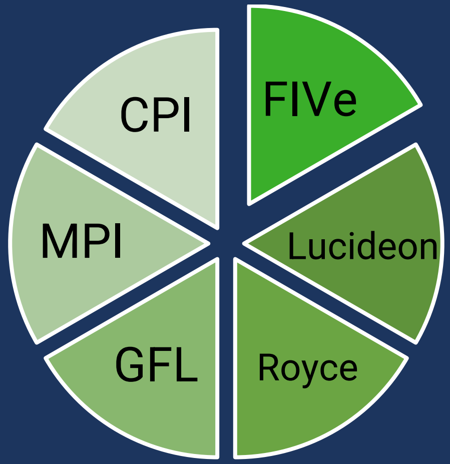
Lucy Smith and Hallam Wheatley
20th March 2024

The Vision



Commercialisation

Idea generation



- Collaboration
- Scale-up innovation ecosystem
- Net zero, sustainability-focussed innovation
- Diverse network

Foundation Industries Ventures (FIVe)

Why?

- Vital technology is not entering the market with a lack of innovation churn.
- Growth is slow.
- Ventures are hesitant to spin out due to high initial risk and market barriers without a demonstrator.
- Poor ED&I across the FIs and high barriers to entry for diverse groups in spin-outs.

This WP will deliver a **robust, externally verified business case** to support the establishment of an incubator and accelerator centre for the commercialisation of new products and processes for the FIs through start-up/spin-out support.

The need

Barriers to starting a company

Support

"The university environment is not conducive for commercialisation. It is not understood, it is often frowned upon"

Finance

"Securing funding in the early period to recruit and operate"

Negotiations

"Uncompromising and inflexible university stalling negotiations"

Barriers to scaling a company

Team

"Growing the team with highly skilled and motivated employees"

Finance

"Investment – again without stability of 2 years runway – nothing is possible to scale"

Market

"Building relationships with first customers who want to explore an emerging technology"

AMION Market Research and Business Case

- Concepts under investigation:
  - Scheme design
  - Funding mechanisms
  - Organisational structure (supported by Burges Salmon to understand legality)
  - Financial forecast

- Aims
  - Not-for-profit
  - Self-sustaining – i.e. not reliant on government funding following the initial set-up stages

Branding

FIVe will be a not-for-profit incubator and accelerator supporting the UK FIs and its supply chains.
The UK Foundation Industries (FIs): metals, ceramics, glass, chemicals, paper, and cement.
FIVe
Incubator
Business support
Access to experts
Bespoke lab space
Ecosystem
Poor innovation churn
Accelerator
Investor hesitancy
Training and coaching
Inward investment
28m
Combined 28M Tn of materials per year
50m
50M Tn of CO2 produced per year
Vital technology not reaching the market

Comms and Business Development

FIVe S&IN

- FIVe S&IN
  - Partner Working Group to be established (FIVe, FISC, TransFIRe, Network+)
  - Review of Regulatory Landscape – AMION
  - Workshops and sandpits for data collection
  - Ongoing comms to report findings
  - Implementation Phase proposal

Next steps

- Presentation of AMION findings to the FISC board
- Induct spinout
- Stakeholder engagement
- Sense checking the AMION findings with relevant stakeholders
- Development of the case for support
- Comms & Marketing
    - LinkedIn page up and running
    - Web page under development
    - Local business engagement in Teesside
        - NEPIC (North East Process Industry Cluster)

Call to action

Foundation Industries Ventures

Foundation Industry Strategy Workshop

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Hallam Wheatley: hallam.wheatley@glass-futures.org

FISC
Foundation Industries Sustainability Consortium

FISC Strategy Workshop

The Foundation Industries Sustainability Consortium (FISC) brings together global leaders in innovation, research and technology from across the cement, metal, glass, ceramic, paper, polymer and chemical industries.

UKRI Innovate UK