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Innovate UK,
EPSRC and ESRC

Transforming Foundation Industries Challenge

Forging a sustainable future

Cementing change in the industries that underpin our world

2020–2025 and beyond

> “By prioritising research and development, embracing cutting-edge technologies and fostering collaboration across sectors and disciplines, we can enhance productivity, drive economic growth, increase resilience and ensure environmental sustainability.”
>
> **Bruce Adderley**, TFI Challenge Director

Forging a sustainable future

Bruce Adderley TFI Challenge Director

In an era defined by the drive towards net zero and sustainability and the increasing importance of resilience and rapid technological advancement, the foundation industries stand at a critical juncture. The chemicals, ceramics, glass, metals, cement, and paper sectors are the backbone of the UK economy. They not only provide essential materials but also underpin many other industries. All sectors now face radical change. This brings both challenges and opportunities. For foundation industries, like other sectors, resilience and adaptability will be key to meeting the challenges of the future.

Investment in innovation is not just about maintaining competitiveness. It is about transforming these industries to meet the demands of a changing world. By prioritising research and development, embracing cutting-edge technologies and fostering collaboration across sectors and disciplines, we can enhance productivity, drive economic growth, increase resilience and ensure environmental sustainability.

I invite you to explore the insights in this document, which showcases the impact of innovation across the foundation industries and highlights the strengths and opportunities of this cross-sector investment. Together, we can build a stronger, more sustainable future for the UK and beyond.

Contents

Introduction

Six manufacturing sectors make up the UK's foundation industries:

- **cement**
- **ceramics**
- **chemicals**
- **glass**
- **paper**
- **metals**

They have a combined turnover of more than £67.5 billion (ONS 2020) and employ more than 250,000 across more than 7,000 businesses. Foundation industries also produce 75% of the materials we use daily. They are a key part of the UK economy and society.

We are supporting transformational change

Transformational change is needed across these industries to meet the UK's net zero commitments. The UK foundation industries are by far the UK's biggest industrial polluters. They produced around 50 million tonnes of CO2 in 2015 or 10% of the total CO2 emitted by UK homes and businesses. More than three-quarters of foundation industry sales are directly to other businesses, so they have a significant impact on the carbon emissions and the dynamism of many other sectors.

The UK also has one of the smallest foundation industry sectors relative to GDP of the Organisation for Economic Co-operation and Development countries. This has led to concerns around resilience.

Research undertaken for UKRI by Enterprise Research Centre in early 2020 found that industry representatives highlighted increased international competition, high energy costs and pressure to reduce CO2 emissions and environmental impact as the greatest challenges.

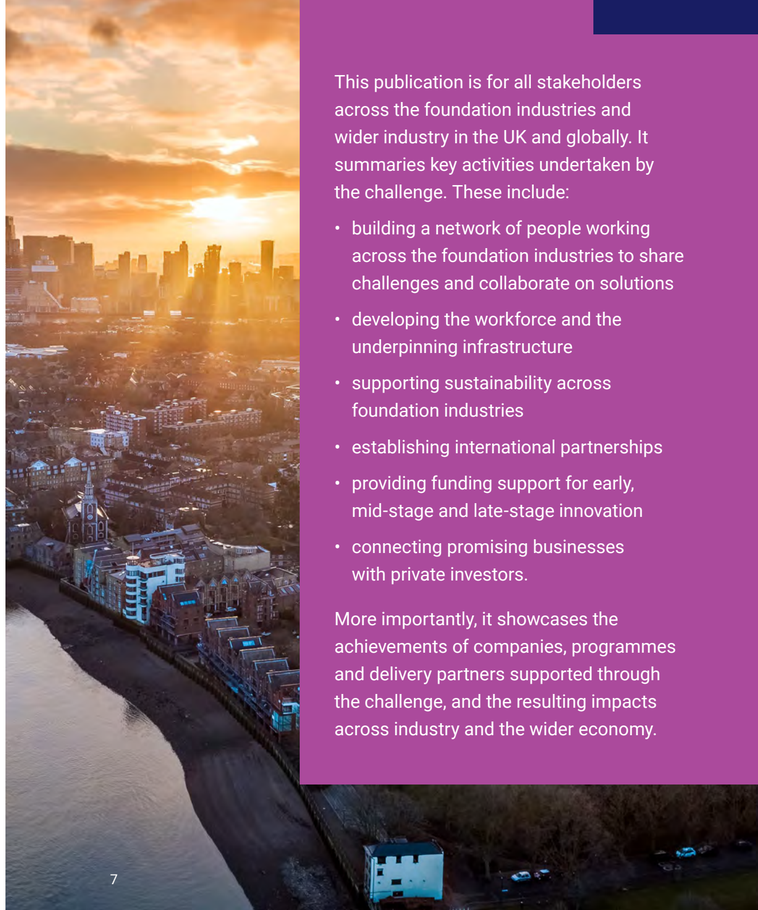
They said they faced financial constraints in adopting new technologies and uncertainty around international trading relationships. They also identified under-developed management and leadership skills as a barrier to innovation. This innovation is, however, essential if the UK is to meet its target of net zero by 2050. It also presents an enormous opportunity for the UK foundation industries as international markets for clean products and technologies grow rapidly.

Innovation is now delivering new production processes to enable foundation industries to become net zero and resource efficient. Cutting edge technology is helping them to increase competitiveness and UK resilience and anchor production in the UK. The UKRI Transforming Foundation Industries Challenge has been at the heart of this work over the last four years.

A £66 million investment

UK Research and Innovation is a non-departmental public body that brings together seven UK research councils, Research England and the UK's innovation agency, Innovate UK. UKRI's Transforming Foundation Industries Challenge is a £66 million programme led by Innovate UK and with input from the Engineering and Physical Sciences Research Council (EPSRC), the Economic and Social Research Council (ESRC) and Innovate UK Business Connect. We are helping the UK's foundation industries become internationally competitive, secure more UK jobs and grow in an environmentally sustainable way.

We have led transformational cross-sector collaboration between these foundation industries and the broader community since the challenge's inception in 2020.



This publication is for all stakeholders across the foundation industries and wider industry in the UK and globally. It summaries key activities undertaken by the challenge. These include:

- building a network of people working across the foundation industries to share challenges and collaborate on solutions
- developing the workforce and the underpinning infrastructure
- supporting sustainability across foundation industries
- establishing international partnerships
- providing funding support for early, mid-stage and late-stage innovation
- connecting promising businesses with private investors.

More importantly, it showcases the achievements of companies, programmes and delivery partners supported through the challenge, and the resulting impacts across industry and the wider economy.

Our achievements

Establishment of the £54 million Glass Futures research and technology centre, which provides state-of-the art equipment for research and development. It is already driving innovation in low-carbon ways of heating glass furnaces.

Invested £33.7 million in business collaborations. Projects have created 3,000 jobs, attracted and realised £275 million in follow-on industry investment and a further £100m in committed investment from industry.

More than 3,600 connections grown across SMEs, large enterprises, academic institutions and research centres that have supported 300 collaborations under the challenge and will underpin future innovation.

FISC

An additional **£40m invested** in world-class demonstration facilities through the **Foundation Industries Sustainability Consortium** (FISC), a collaboration between the Centre for Process Innovation, Glass Futures Ltd, the Materials Processing Institute, Lucideon and the Henry Royce Institute.

TRANSFIRE

Establishment of the **TransFIRe** (Transforming Foundation Industries Research and Innovation) hub to bring academia and industry together to address the need for sustainability across the foundation industries. It has **diverted more than 10,000 tonnes of waste from landfill** through useful sharing of by-products and identified **potential CO2 reductions of up to 25%.**

Pioneering demand-led innovation across the foundation industries to break barriers holding back technologies that could offer new sustainable solutions.

Programmes to develop future leaders and innovators among rising talent, including **80 women leaders** supported and developing those who have followed a vocational path into the foundation industries.

TFI NETWORK+

Creation of TFI Network+, a community of 740 university, research and technology, and business participants working on multi-industry research to support foundation industries.

Attracted **£100 million of private investment** into businesses by establishing a community of private investors and matching businesses we funded with selected investors.

Built a significant partnership between the foundation industries in the UK and India that is driving innovation of benefit to both countries, including **investing £10m in UK-India business collaborations.**

£66m
Challenge investment

Has unlocked
£275m
industry follow-on investment

Plus another
£100m
committed by industry

Leading to
3000
new jobs

3,600
industry connections

£54m
Glass Futures centre

297
industry collaborations

80 **women leaders supported**

£40m
for industry test beds

£10m **for UK-India collaborations**

£100m
attracted from private investors

Building a network of people

Building and growing a strong network across the sectors was fundamental to the success of the challenge and remains fundamental to the future sustainability of these industries.

A key achievement has been the creation of a robust and diverse network through different but connected initiatives.

The TFI Network+ brought together academic expertise from across the UK, and the TransFIRe hub (see page 40) developed an industry-to-academic network with more than 100 industrial members.

We also established and grew a cross-sector network of more than 3,600 contacts from SMEs, large enterprises, academic institutions and research centres. The network was fundamental to collaborative projects covered in later sections of this report and to the development of a shared identity across the foundation industries.

As the programme comes to its end, these achievements provide a strong foundation for future growth and development.

Creating a dynamic platform for collaboration

The challenge created a dynamic platform for collaboration over the past four years, bringing together key players across sectors through a comprehensive schedule of more than 50 events, held both in person and virtually. These events ran between October 2020 and October 2024 and attracted 2,353 unique delegates, with representation from SMEs, large corporates, academic institutions and research centres.

The programme facilitated more than 470 introductions, helping businesses and researchers connect, share knowledge and explore collaborative opportunities. These efforts have resulted in 297 collaborations across the sector, helping to foster innovation and develop cutting-edge solutions for the foundation industries.

Events brought industry together

Events covered a wide range of topics, reflecting the diverse challenges and opportunities in the foundation industries. Highlights included:

- a cohort event in June 2022, which brought together the community at a pivotal point mid-way through the challenge to share experience and identify future opportunities
- Materials Research Exchange, Futurebuild and UK Metals Expo, where representatives exhibited their innovative solutions for more sustainable construction, metals and other industries
- multiple workshops focused on critical topics or opportunities, for example the Horizon Europe insight day or Sustaining the Future – the case for investing in the foundation industries. These targeted events provided a platform for networking and knowledge sharing on priority topics to the attendees and the foundation industries.

ADAPTAVATE

Adaptavate, a business that specialises in taking CO2 from the atmosphere and putting it into building materials such as wallboards, won the prestigious Big Innovation Pitch award at Futurebuild 2024. The company was supported with a grant and, under the Investor Partner programme, with funding to build a pilot line.

Watch more videos from Futurebuild 2024

"The award really validates the work that we're doing and that Innovate UK have helped us to bring to fruition."

Tom Robinson,
Chief Executive and Founder,
Adaptavate

Significant industry collaborations established

These connections have resulted in significant collaboration across the sector, including household names such as Unilever, Diageo and National Highways working with foundation industry stalwarts such as Tata Steel, NSG Pilkington and Aggregate Industries and with start-up companies and university spin-outs.

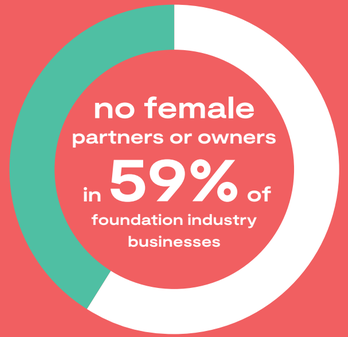
The depth and breadth of the network has led to collaborations that are reinventing supply chains. The network helped to find partners for the Flue2Chem project to complete a new UK supply chain to capture industrial waste gases and convert them into sustainable materials for consumer products made by Unilever and other partners.

We introduced Diageo to Keen Limited to help in its search for packaging products with lower embodied carbon. This led to the development of the British Aluminium Consortium for Advanced Alloys (BACALL), which is re-imagining the supply chain for aluminium products and helping to create a step change in aluminium recycling in the UK.

Change needed to improve representation of women

Attracting the best talent to a strong and diverse workforce is key to meeting ambitious targets for the foundation industries. Recent **research on equality, diversity and inclusion in UK foundation industries** revealed:

only 5% of businesses had two or more female representatives among senior management



Where women are represented, they tend to be in non-production roles, such as administration, support services, human resources or finance. While there have been pockets of positive action, efforts at company level alone are not enough. We need sector-wide collaboration to achieve significant change in the timescales required.

Women innovators join new initiative

We set up the Women Innovators in Foundation Industries (WINFI). This is a community of professionals and organisations that advocates for and champions women working in foundation industries. It aims to increase the number of women innovators with new ideas, skills and perspectives to help achieve industry's 2050 goals.

WINFI's objectives are to:

- raise the profile of women innovators as thought leaders in foundation industries
- support businesses to define and implement gender diversity strategy
- enable the 'inner innovator' of professional women in foundation industries
- create networking opportunities for women, allies and other stakeholders to foster innovation, collaborations and partnerships.

"I am proud to have been invited to share my passion and achievements in digital construction to an audience of sector leaders, colleagues, and peers. Drawing on my own experience in the industry, I know the important role leaders can play in supporting women by implementing initiatives to overcome everyday unconscious biases and becoming a mentor to guide junior personnel as they begin their career. I would encourage leaders from across the foundation industries to get involved in helping to promote a more inclusive environment for women for the betterment of our sector."

Marzia Bolpagni, Head of BIM International at Mace

We organised networking events across the country to discuss relevant topics to the industry including circular economy, digitisation and intrapreneurship. The aim was to to share better ways of working and new ideas and encourage cross-sector collaboration. Each event highlighted the impact women are having on the industries through research, innovation and leadership.

TFI NETWORK+ delivers new knowledge

We awarded £2 million through EPSRC to support the formation of the TFI Network+ (TFIN+). It has created a community of 740 university, research and technology, and business participants working on multi-industry research. It has led to a sense of community across what were traditionally seen as disparate industrial sectors. TFIN+ has also delivered many new concepts and innovative adaptations of existing knowledge that are key to a competitive and sustainable future for the foundation industries.

Follow-on collaborative activities will help with wider adoption of carbon mitigation and environmentally sustainable technologies, and the diverse skills developed will ensure the continued success of the foundation industries in the UK.

In the four years since its launch, TFIN+ has helped to investigate and offer solutions to challenges the foundation industries face, such as stringent environmental legislation, overseas competition, disruption to supply chains, energy prices and an ageing workforce.

See the brochure of projects

Stakeholder events and workshops

£1.4 million in funding for 34 proof of concept projects of up to six months

Creating an inclusive environment for those working in, with or considering a future career in the foundation industries

Workshops bring stakeholders together

TFIN+ organised or managed with partner organisations 42 events involving more than 4,000 participants working at different career levels in various organisations. Participants discussed opportunities and learnt how different sectors were approaching solutions to the challenges.

The events helped to create a sense of identity around the foundation industries and to build trust. An extensive marketing campaign reached more than 900 newsletter subscribers and 1,200 LinkedIn profiles.

Projects win £1.4 million for studies

Funding of **£1.4 million** was awarded to **34 projects**, through five themed opportunities based on priority challenges identified by the wider community.

Watch 10 case study videos from TFIN+

Projects secured a further

£434,000

of in-kind support from 36 partner companies that recognised the value and potential applications of the science and technology.

Project leaders have since secured a further

£3.5 million

of public or private funding to continue developing their ideas. Some have already demonstrated significant impact on the partner companies or the applicants.

Heat recovery technology could save costs and CO2

Researchers at Brunel University worked with Econotherm Ltd on a proof of concept of a novel flat heat pipe heat recovery system to capture high temperature waste heat. The project believes the technology could be used to improve efficiency, save costs and reduce CO2 emissions in the steel and cement industries.

“This project allowed us to deliver a system to show companies a real-life implementation of the technology where actual impacts could be felt. It showed companies there is a viable solution, and we are following up and working with these companies on scaling up.”

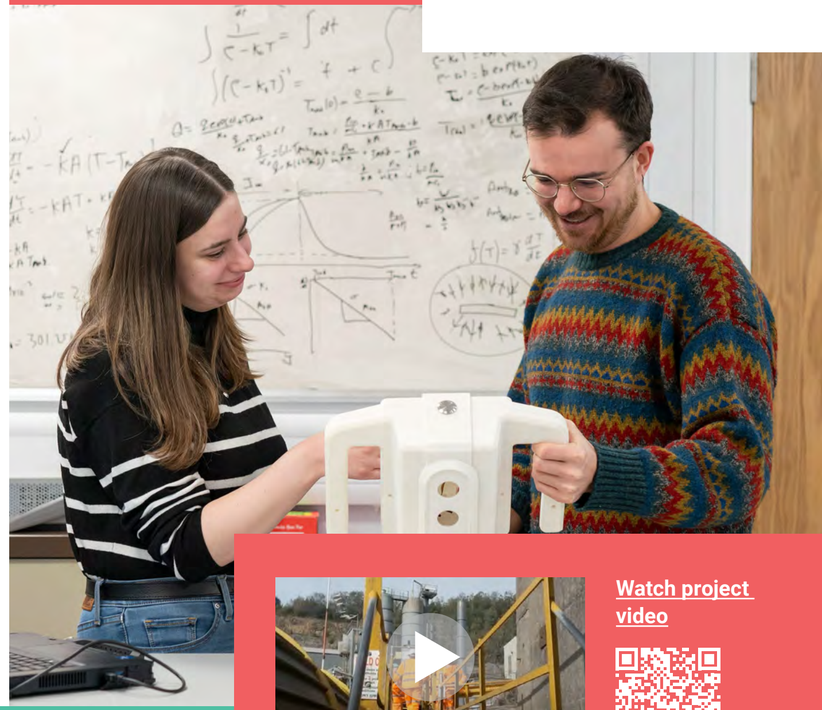
Professor Hussam Jouhara, Brunel University London

Creating an inclusive environment

TFIN+ helped to develop current and future skills required for the foundation industries.

School pupils learnt about sustainability, innovation and manufacturing in a series of events co-produced with the Engineering Development Trust.

Three businesses from different foundation industry sectors piloted a unique development and coaching proposition that empowered businesses to co-design and deliver equality, diversity and inclusion culture change. The pilots used innovative top-down and bottom-up approaches, participation and principles of co-production.



Watch project video

Skills and infrastructure vital to future success

The success of the foundation industries depends on developing the future workforce and underpinning infrastructure. Both are critical for these industries to develop and adopt the technological advancements needed to meet evolving market demands.

Significant workforce challenges identified

We commissioned a study in 2020 to investigate the challenges for the future foundation industries workforce. SQW Group conducted a thorough investigation for Transforming Foundation Industries – Future Skills. The report's findings and recommendations were used to plan and deliver activities to address the following challenges.

Ageing workforce

Many workers are reaching retirement age and leaving a potential skills gap. Ensuring that valuable institutional knowledge is transferred to younger employees is essential but often inadequately managed.

Skills mismatch

Rapid technological changes, including automation and digitalisation require new skills that current workforces lack. Existing training programmes may not align with the evolving skill requirements of modern workplaces.

Attracting talent

The foundation industries are often perceived as traditional and low-tech, making it difficult to attract younger talent interested in innovative and dynamic careers.

Diversity and inclusion

Women are significantly underrepresented, especially in technical and leadership roles. Lack of diversity limits the range of perspectives and ideas and affects innovation and problem-solving.

Continuous learning and development

Promoting a culture of continuous learning is essential but often not prioritised. Regularly updating skills to keep pace with technological and process advancements requires a systematic approach.

Industry–academic collaboration

A disconnect between academic institutions and industry needs leads to graduates not being fully prepared for roles. Collaborations between industry and academia that drive innovation and practical applications can be limited, affecting the ability to stay ahead of technological advancements.

Regulatory and compliance knowledge

Workers must be continuously educated on increasingly stringent environmental and safety regulations. Integrating sustainable practices requires specific knowledge and skills that are not yet widespread in foundation industries.

Encouraging the next generation

We commissioned a report on equality, diversity and inclusion in UK foundation industries, which was delivered by Enterprise Research Centre (ERC). The report highlighted an ageing workforce and limited female representation. Female employees were also more likely to be working in non-production roles. Relatively few foundation industry businesses had female owners and partners. Industry representatives acknowledged the issues and potential impact on the future, but, with limiting resources, they cannot solve all of them.

Our leadership programmes and activities to attract a young workforce have supported foundation industries in diversifying their workforce. These activities centred around improving the sector image and developing management and leadership skills.

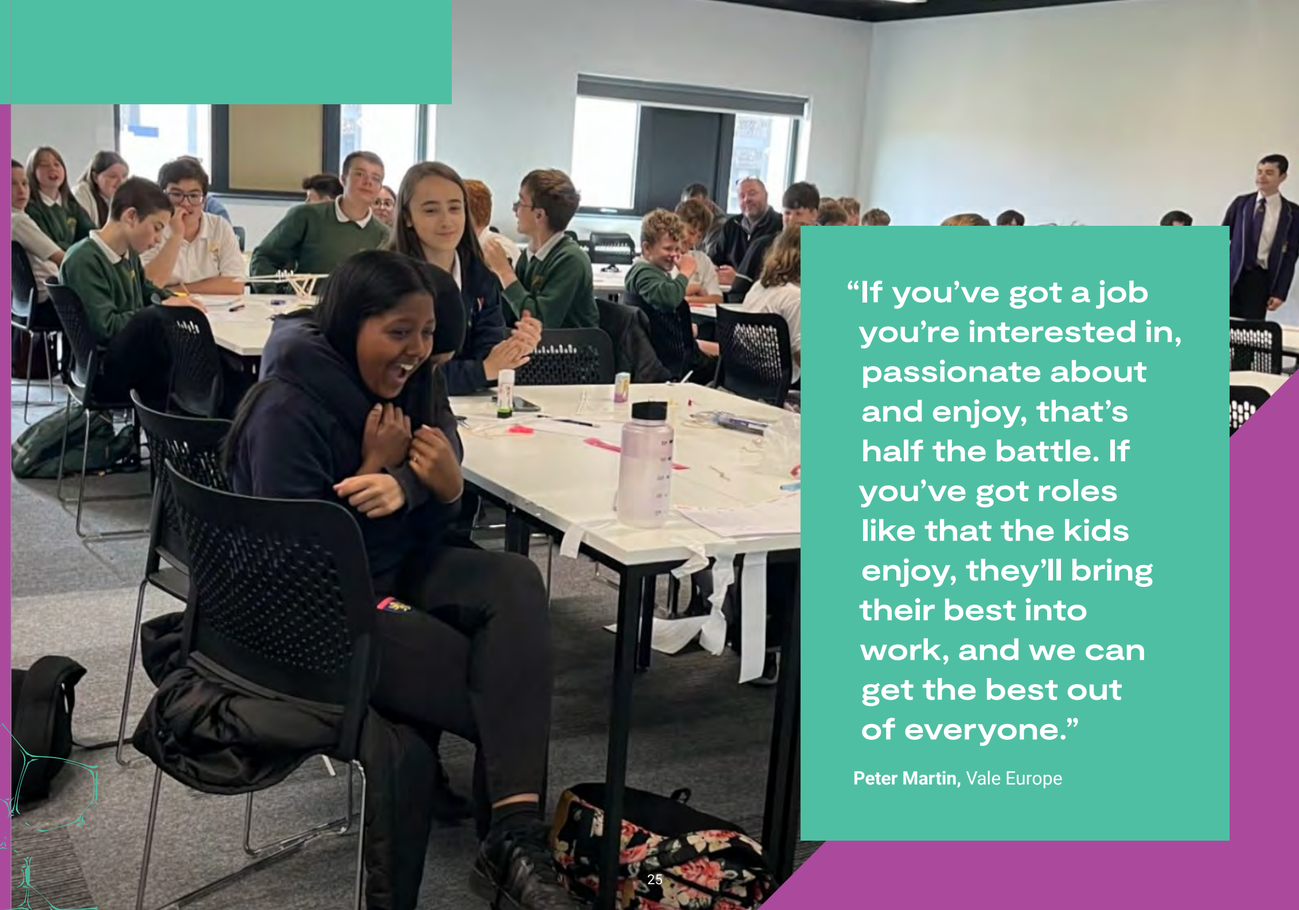
Improving sector image and attractiveness

Foundation industries are commonly seen as polluters that cause environmental damage and undertake little innovation to tackle the challenge. There is a huge opportunity for the next generation of engineers, designers, scientists and others to help meet the UK's material demands while reducing environmental impact.

Youngsters learn about sustainability

We partnered with the Engineering Development Trust (EDT) to deliver a Challenger Day workshop on innovation and sustainability to increase awareness of foundation industries among younger age groups. School pupils in the Swansea area learnt about sustainability and manufacturing in South Wales, a region with a long heritage in foundation industries.

Key stage three students from several schools were given examples of what these industries produce and why they are so crucial in South Wales through a series of fun activities. The activities, developed by the Engineering Development Trust, introduced different industrial decarbonisation approaches being considered in South Wales and the concept of a circular economy. Pupils were joined by industrial representatives from Vale Europe and Tata Steel.



> "If you've got a job you're interested in, passionate about and enjoy, that's half the battle. If you've got roles like that the kids enjoy, they'll bring their best into work, and we can get the best out of everyone."
>
> **Peter Martin,** Vale Europe

Hackathons promote creative thinking

We partnered with Materials and Design Exchange (MaDE) to deliver a series of hackathons aimed at encouraging interdisciplinary networks and improving awareness of foundation industries.

These events brought together groups of students and recent graduates in design and engineering to rapidly create new solutions to grand societal challenges relevant to foundation industries. Each event was held at a prominent exhibition and involved student teams drawing from their own experience and content at the show to pitch their solution to a panel of judges.

The hackathons highlighted the fundamental link between the foundation industries and our society and the need for creative thinking to develop solutions for the future.

“The Hackathon allowed me to collaborate with talented peers and apply my skills to address real-world challenges. I gained insights into rapid ideation, problem-solving and teamwork, which I believe will greatly benefit my future endeavours.”

Participant at the Futurebuild Hackathon March 2024

Management and leadership developed

Diversity in leadership is proven to have positive impacts on innovation and business results. We promoted the development of management and leadership skills in the foundation industries from a range of different people in **three key ways:**

- a future leaders group that helped to shape the strategy of the challenge
- a programme to develop women leaders
- a programme to develop employees who had taken a vocational training route into the industries

Leaders group fostered mentoring and innovation

The Future Leaders Group, formed in 2020, brought together diverse voices to shape the strategy for the Transforming Foundation Industries Challenge programme. Through quarterly meetings and focused subgroups dedicated to communications, equality, diversity and inclusion, innovation and sustainability and circular economy, the group made significant contributions. They amplified their reach through webinars and conferences, shaped diversity and inclusion initiatives, fostered collaborative research projects, and organised impactful webinars on sustainability challenges.

The group’s impact extended beyond its advisory role, inspiring members to continue collaborating and driving sustainable innovation. This led to the creation of FIVe (see page 62), a platform supporting start-ups and spin-outs working towards a net-zero future in the foundation industries.

Although the formal group concluded in 2023, its legacy continues through FIVe and the ongoing network of mentors and innovators committed to a sustainable future for the foundation industries.

"I saw a clear, concerted effort to include people from across the entire spectrum of the foundation industries. When becoming an engineer, it can be easy to 'silo yourself off' into a specific niche and lose perspective. Joining the Future Leaders Group allowed us all to leave those silos, come together, view the foundation industries holistically and work collaboratively."

Future Leaders Group member

Programme developed women leaders

The six sectors that make up the foundation industries employ more than 250,000 people yet they lack women in leadership roles in any meaningful numbers. Innovation is key to the future of foundation industries. An increase in diversity, with female leadership at the forefront, will drive more innovation.

We supported 80 women to participate in a 12-month women's leadership programme

Objectives for participants included:

- understanding and overcoming imposter syndrome
- building strong relationships that benefit everyone
- mastering time, energy and focus
- knowing influence and negotiating win-wins
- making superior decisions and solving complicated problems
- creating opportunities for themselves and for other women across the foundation industries.

"The course has helped me identify strong team members and develop them such that together we are driving innovative technology within our organisation."

Leadership programme member

"Directly due to this course I have started a potential collaboration with a company that employs someone in my cohort."

Leadership group member

Developing leaders from vocational background

People sometimes undervalue themselves or their ability to progress into leadership roles if they have followed a vocational or apprenticeship route. The success of the women's leadership programme led us to set up a leadership programme for early managers from a vocational training background.

The successful programme was designed with specific emphasis on building confidence, countering imposter syndrome and addressing the imbalance between those academically educated and trained and those who have chosen a vocational route.

Business support helped smaller companies

SMEs can find themselves resource, time and cash constrained. At the same time, they must learn new skills, rapidly develop know-how and expand network connections. We have supported SMEs through innovation masterclasses on grants, loans, Knowledge Transfer Partnerships and how to make applications.

Collaboration and networking activities included use of tools such as the Innovate UK Innovation Canvas to help identify innovative projects. Activities also allowed businesses to pitch project ideas and collaboration needs to organisations that can sometimes be out of reach, allowing connections to be made virtually and in person.

An Innovation Caucus report commissioned by the challenge set out to explore the innovation intentions of foundation industry SMEs, providing a tool to diagnose areas where organisations could benefit from support.

We also commissioned Carbon Limiting Technologies to deliver a programme supporting SMEs who were just starting out on their innovation journey towards net zero. And we launched the Transforming Foundation Industries Investor Partner programme (see page 60) to give SMEs access to capital investment and grant funding to develop and commercialise innovations.

Read Innovation Caucus report

Business advice was extremely helpful

Parkinson Spencer Refractories designs and manufactures industry-leading glass conditioning solutions. Its production is energy intensive and faces similar challenges to those found across the foundation industries.

Watch the Parkinson Spencer Refractories video

“We found the support of Innovate UK Business Connect in giving feedback on our first application extremely helpful. They not only asked the right questions to make sure that we fully addressed the questions on the application form, but also shared their experience in creating a realistic research plan.”

Jafar Daji, Technical Manager,
Parkinson Spencer
Refractories Ltd

Research centre demonstrates sustainable future for glass

Our single largest investment was the £16.5 million for the **Glass Futures research and development centre** in St Helens. The Innovate UK investment sits alongside investment from the Liverpool City Region and St Helens Council and from industry to make a total of over £54 million. The centre features state-of-the-art equipment and can produce 30 tonnes of glass a day for research and development into products such as bottles, windscreens and windows.

It is demonstrating new glass compositions, production methods and disruptive technologies that are making glass and other materials zero carbon and sustainable and improving industry efficiency.

The facility is operated by Glass Futures Ltd, a global not-for-profit research and technology organisation. It aims to:

- **foster collaboration between industry, academia and government**
- **drive innovation**
- **enhance the competitiveness of the UK glass sector**
- **promote sustainable practices and reduce carbon emissions**

Partners invest £54 million in future of glass

Establishing Glass Futures is a strategic move to maintain the UK's competitive edge in a global market increasingly focused on sustainability. Government, industry and local stakeholders have committed £54 million in a collaborative effort to enhance the glass sector in the UK.

The glass industry significantly contributes to sectors including construction, automotive and packaging and is responsible for around 0.5% of the UK's total carbon emissions. The development and scaling of new production methods for zero carbon glass is a growth opportunity for the UK.

Pilot plant is a standout feature

A versatile pilot plant is a standout feature of Glass Futures. It includes an industrial-scale glass melting furnace capable of producing up to 30 tonnes per day of glass. This flexibility allows researchers and manufacturers to experiment with new glass formulations and production techniques without the financial risks associated with large-scale manufacturing. The facility also houses advanced research laboratories equipped with cutting-edge technology for material analysis and testing.

Glass Futures is designed to be highly energy-efficient, incorporating renewable energy sources and advanced technologies to minimise its carbon footprint. The emphasis on sustainability is further reflected in the facility's aim to develop new glass compositions that require less energy to produce and can be recycled more effectively, alongside assessing and demonstrating the feasibility for switching the glass furnace to electric, hydrogen and/or biofuels-based power sources.

It also plays a critical role in promoting the circular economy in the glass sector. By developing processes that facilitate the use of increased levels of recycled glass materials, it is helping to reduce waste and conserve resources.

Centre is developing training and skills

Training and skills development are a core part of the work of Glass Futures. It offers specialised training programmes that will equip the workforce across the foundation industries with the necessary skills to thrive in an area that increasingly prioritises sustainability and technological advancements.

Work with the local community is central to this effort. Glass Futures is collaborating with local schools and educational institutions to inspire the next generation of engineers and scientists and help to build a sustainable talent pipeline for the industry.

Centre trials innovative furnace heating

Glass Futures was established in 2020 and has already undertaken projects covering new furnace technologies, control and automation, coatings and forming technologies and routes to increase the use of recycled materials.

British Glass has identified electric boosting – injection of electrodes into a glass bath to provide efficient heating – as having the potential to reduce CO2 by 56% annually and offer up to 200 MWH load balancing for the grid. Glass Futures and partners are exploring the efficiency and quality of this innovative electric melting as a way of providing 40-50% of the melting capacity in conventional fossil-fuel-fired glass furnaces.

It will enable a transition to so-called super-boost hybrid furnaces by 2040 and unlock this carbon reduction

Glass Futures has also explored economically and technologically attractive biofuels for a range of industrial glass and ceramic furnace sites. This has enabled trials at some of the world's largest glass manufacturers, including Pilkington, O-I, Ardagh and Encirc. These projects are demonstrating fuels that can provide a quick, economical route to decarbonising existing furnaces and kilns and signal a longer-term route to carbon negative industrial manufacturing using carbon capture.

Following a feasibility project to fire 100% hydrogen on its combustion test rig, Glass Futures is working alongside Ceramics UK to demonstrate 100% hydrogen-firing technologies for the two main types of kiln used across more than 150 manufacturing sites.

Switching kilns to hydrogen combustion has the potential to reduce UK CO2 by up to 780kt a year

Consortium offers world-class demonstration facilities

The Foundation Industries Sustainability Consortium (FISC) is a collaboration between the Centre for Process Innovation, Glass Futures Ltd, the Materials Processing Institute, Lucideon and the Henry Royce Institute. Together these world-class research facilities offer equipment and expertise to demonstrate new technologies at a commercially relevant scale. By working together, these centres address sustainability challenges shared across the foundation industries.

Innovate UK invested £40 million in the FISC Economic Material Innovation for Sustainable and Efficient use of Resources (ECONOMISER) programme to support this collaboration and further develop cross sector working

The programme developed a network of scale-up centres to supplement existing facilities and support industry and academic innovation in carbon reduction, process improvement and product development. This focused support to foundation industries across **five themes**:

- circular economy
- process optimisation
- alternative fuels
- new material development
- digital controls and sensors

The collaboration across sectors and between industry, academia and government encourages sharing of knowledge and best practice to improve energy efficiency and reduce waste.

By developing a test bed of facilities that enables companies to 'try before they buy', it makes it easier for business to develop innovative approaches to decarbonisation. Industry can assess the benefit, explore how to work with the technology and then integrate those technologies into manufacturing sites.

Driving the innovation industry needs

Innovation is key to meeting the need of all industries for more energy-efficient and sustainable ways of working. It is also a huge opportunity for foundation industry businesses to develop new and important products and services that will meet the needs of their customers and drive growth.

We set up the TransFIRe (Transforming Foundation Industries Research and Innovation) hub to bring academia and industry together in pursuit of these goals. We have also supported innovation that will provide the solutions demanded by industry.

TRANSFIRE

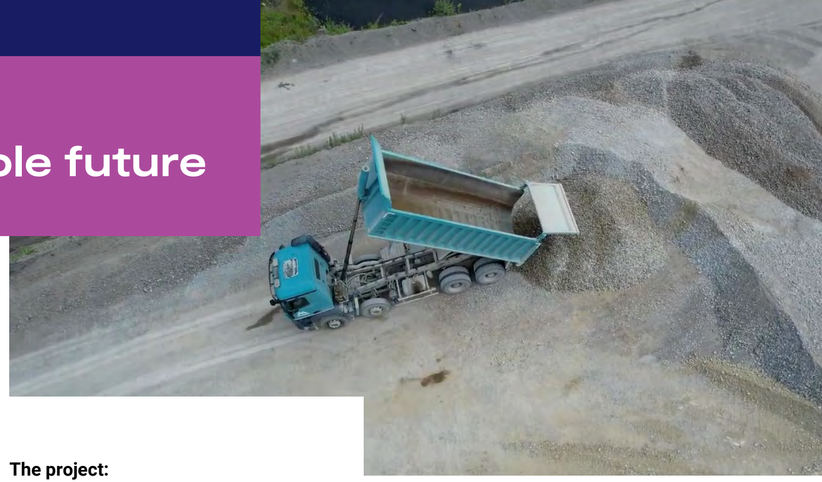
Driving a sustainable future

The TransFIRe hub, delivered through EPSRC, is a collaborative initiative funded by Innovate UK. It brought academia and industry together to address the pressing need for sustainability in the UK's foundation industries.

12 research organisations

80 project partners

driving innovation and efficiency through interdisciplinary research and best practices



The project:

- identified potential for energy savings of up to 20% and CO_2 emissions reductions of up to 25%
- diverted more than 10,000 tonnes of waste from landfill through useful sharing of by-products (industrial symbiosis)
- identified barriers including lack of recycling infrastructure, regulatory uncertainties and the high cost of energy
- worked with local communities to foster collaboration and economic development
- championed equality, diversity and inclusion in foundation industries
- developed sustainable solutions through knowledge exchange and pilot studies.

Consortium established to ensure future progress

TransFIRe has fundamentally shifted the landscape for the UK's foundation industries, fostering a culture of collaboration and sustainability. The Foundation Industries Sustainability Consortium will ensure ongoing progress towards a low-carbon and resilient industrial future including:

- addressing key challenges such as optimising existing plants for efficiency
- developing next-generation sustainable processes and products
- advancing the circular economy
- cultivating a skilled workforce to drive innovation

Read the final TransFIRe report

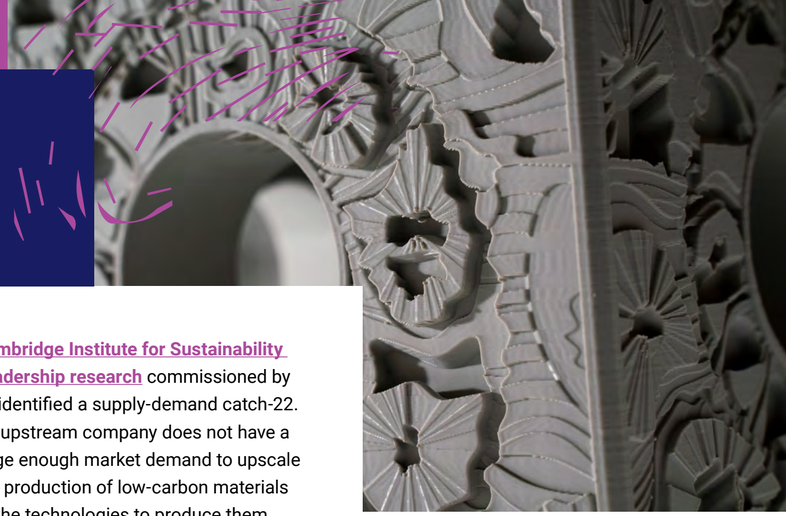
TransFIRe aids Royal Mint

TransFIRe worked with The Royal Mint on an innovative project to extract precious metals from the circuit boards of electronic waste such as laptops and mobiles (see pages 33 & 34 of the full report). The material could be used to create an eco-friendly jewellery line.

"TransFIRe has been instrumental in advancing The Royal Mint's sustainable practices and exploring new collaborative opportunities in electronic waste recycling."

Tony Baker, Director of Manufacturing Innovation, The Royal Mint

Innovation meets demand for sustainability



Materials supplied by foundation industries are present in products made by all industries and represent a significant proportion of their embodied carbon. The foundation industries therefore have a major impact on the indirect emissions of many large organisations that have committed to reducing their emissions and achieving net zero.

There are examples where demand for more sustainable materials is influencing traditional supply chains and encouraging more collaboration along those chains. But there is a much greater opportunity. The challenge has been working to translate the demand for more sustainable materials into innovation and investment into the foundation industries.

Cambridge Institute for Sustainability Leadership research commissioned by us identified a supply-demand catch-22. An upstream company does not have a large enough market demand to upscale the production of low-carbon materials or the technologies to produce them. Downstream companies cannot risk investing in alternative technologies before they have a stable supply of upstream low-carbon materials or products.

This hampers the scale-up of new technologies. Demand-led innovation offers a mechanism to break this catch-22 because it is innovation incentivised by a gap in the market for a product or service that consumers want – and for which they would be willing to pay. The opportunity here was discussed in a roundtable at Innovation Zero with representatives from different organisations taking action in this area, including First Movers Coalition, part of the World Economic Forum.

We investigated how demand-led innovation could be applied in three of the main markets for the foundation industries – construction, packaging and automotive.

Commitment aims to derisk decarbonised concrete

BRE Group studied the potential for demand-led innovation in construction and highlighted cement and concrete as products with potential.

Concrete is the most widely used man-made substance on the planet and contributes to 8% of the global carbon footprint, most of which is attributed to production of cement. There are many innovators developing new solutions to decarbonise concrete, but the scale of production and the economics involved mean it is very difficult to scale-up new technologies.

Knowledge developed through the challenge and the challenge team's expertise has inspired other initiatives beyond our programme. For example, Innovate UK is piloting a project to develop an advance market commitment (AMC) to help decarbonise concrete. An AMC is a binding commitment to make a market for an innovative product or service that is not yet commercially developed. It has been used successfully in the development of vaccines.

Innovate UK funded seven demonstration projects that will help to decarbonise the UK concrete industry and contribute to the creation of an advance market commitment for concrete.

Benchmarking helps set targets for lower carbon concrete

Adoption of innovative solutions in concrete is also hampered by clear comparison between different solutions. For example, there is no shared definition of 'low carbon' or, more appropriately, 'lower carbon' concrete in the UK concrete industry.

We supported work by ARUP that developed an embodied carbon classification scheme to help those across the value chain to make informed decisions, set targets for market interventions and accelerate the development of the market for lower carbon concrete.

The classification work was led by ARUP materials specialist Dr Fragkoulis Kanavaris. It has been adopted worldwide and is helping industry set low-carbon targets and policies.

Dr Kanavaris's work on this and on achieving a

30–60% reduction in CO_2 emissions

across a variety of construction projects, including HS2, led to him receiving the Sir Henry Royce Medal from the Institute of Engineering and Technology.

The medal is awarded to an early career professional who has excelled in the workplace.

Projects look at key areas for packaging

A **scoping study by Oakdene Hollins** identified three potential areas for demand-led innovation in packaging:

- accurately identifying low-impact resources and production processes
- mainstreaming reusable and refillable packaging
- expanding kerbside recycling schemes to include flexible films.

Various projects are addressing these areas. They require systemic changes to existing practices across multiple material flows. Innovate UK is continuing to work with different stakeholders to address these areas.

Materials innovation offers promise for automotive use

Ricardo investigated the opportunities for demand-led innovation in automotive. It identified **three main areas**:

- **alternative materials to reduce vehicle weight**
- **lower embodied carbon materials**
- **increasing circularity of materials with greater recycled content and greater recyclability of the vehicle at end-of-life**

Projects are underway in each of these three areas, but further work is needed including on:

- material separation technologies
- vehicle design that facilitates disassembly
- adoption of lightweight and high recycled content materials
- closed-loop innovation bringing together vehicle end-of-life and recycling industry with automotive manufacturing.

The report clearly identifies great potential in this area, which will be considered in future programme plans.

International partnerships are a big opportunity

The UK is a world leader in development of technologies and processes that will unlock sustainable materials production and allow the UK to reach net zero. However, in a global market, collaboration and partnerships across borders are essential to creating market opportunities and making use of the best technologies available. This is particularly pertinent for the UK foundation industries as many businesses are internationally owned. Developing economies also represent a major market opportunity.

The challenge has forged strategic partnerships with India, Germany and Japan to encourage the innovation developed through the challenge to go international and to help UK businesses to benefit from working with overseas innovators.

India identified as a key partner

We identified India early on as an important potential international collaborator. Its size and development mean its foundation industries are much larger and are investing more rapidly in modern plant than the UK. India shares our eagerness to decarbonise foundation industries.

The collaboration started with the **Foundation Industries Lab to Lab India Collaboration**, funded by UK Research and Innovation (UKRI) India. Projects successfully delivered included:

Liverpool John Moores University
Development of a low-carbon cementitious material by recycling calcium carbide residue waste from foundation industries to decarbonise the construction sector

Durham University
UK-India foundation industries sustainable thermal energy management collaboration

Fraunhofer UK Research
Multi-functional fibre-sensing for foundation industry process monitoring

Aston University
Waste heat recovery and reuse in foundation industries

Glass Futures
UK-India Lab-to-Lab collaboration in glass manufacturing and research

Manufacturing Technology Centre
Recovery of material value by reuse of metal machining waste as high-value powder feedstock

London South Bank University
Recycling construction waste aggregates into new building blocks with digital manufacturing methods

UK-India study reveals promising ideas for metal recycling

Metal manufacturing produces a significant amount of waste through operations such as turning and machining. However, current recycling methods often produce low yields and poor feedstock.

The Manufacturing Technology Centre led a project to explore potential solutions with partners in India. It built a strong network with five Indian research and technology centres and with businesses working in the metal recycling sector. The partners identified opportunities to work together on metal recycling and are seeking funding to support the most promising ones.

Find out more about lab-to-lab projects with India.

UK-India missions lead to £10 million collaboration

The challenge followed up the success of these collaborations with the virtual global expert mission to India in March 2022.

UK and India experts from all six foundation industries participated in a week of workshops and discussions, both sector-focused and theme-focused. Whilst the UK delegates had become accustomed to working across the foundation industry sectors, their Indian counterparts were meeting people from outside their sectors for the first time and saw great value in this.

We published a report on the mission, **Online Global Expert Mission: Transforming Foundation Industries in India**.

We ran a global business innovation programme to India in February 2023 designed to help ambitious businesses collaborate and expand in new markets. The delegation visited Kolkata and Ahmedabad during the week-long visit.

The UK hosted an inward mission from India in April 2023. Participants visited Liverpool and Coventry during a week-long tour. Some of the delegates of the UK-India global expert mission were able to participate.

All this activity culminated in a bilateral £10 million collaborative research and development funding opportunity and created connections and new collaborations between foundation industries in the UK and India.

Projects win major investment and create 3,000 jobs

We invested

£33.7m

across eight funding programmes to support businesses developing innovative solutions

to the challenges facing the foundation industries.

Our aim was to

attract a further

£83m

in co-investment towards these projects.

So far, projects have attracted and

realised

£275m

in co-investment, including £165 million for industry innovation.

A further £100 million has been committed.

Funded projects have also made **17 patent applications,** and they reported that around **3,000 jobs** had been created.

See Shaping the Future for the Foundation Industries in the UK for details of some of the projects supported by the challenge.

Watch a series of videos about funded businesses on the TFI Challenge

Early-stage funding set foundations for the challenge

£2.4m

Fast Start funding opportunity supported 12 collaborative projects.

This opportunity was launched in October 2019 and was the challenge's first. It required cross-sector collaboration and set the foundations for the network that formed during the remainder of the challenge.

We further supported early-stage developments of new technologies, processes and ideas through additional funding opportunities.

The projects are highlighted in the Shaping the Future for the Foundation Industries in the UK: Fast Start Projects Showcase brochure.

This opportunity and others that followed allowed industries to demonstrate the feasibility of ideas and then take them to large-scale projects.

The BACpack feasibility study examined the recycling of scrap for the manufacture of low-carbon aluminium sheet for packaging and other large-scale applications in the UK. It led to the formation of the British Aluminium Consortium for Advanced Alloys (BACALL), an initiative developing a large-scale aluminium recycling facility.

Innovative ceramics manufacturer Alusid led a project to make the world's first ceramic glazed tiles from 100% recycled materials. Developments led to a new product line, Luca.

Binding Solutions Limited worked with the Materials Processing Institute to develop its composite pellet technology. The work led to a new product available for electric-arc furnace processing that will help to accelerate decarbonisation of steel-making.

Low-carbon buildings cut emissions and can be reused

Property consultants Mace Group led a project to pioneer energy-efficient, dismantlable and reusable building structures. It trialled recycled steel and cement-free concrete.

The approach could:

cut embodied carbon by up to 80%

reduce vehicle movements to a site by 40%

reduce labour resources for steel frame erection by 60%

Mace is already using the techniques in live tender bids.

"Pre-cast construction is very popular in Europe, and there is the potential to increase its growth in the UK. This project has taken away the risk for clients of testing these materials on site and demonstrated that not only can they construct a building with a lower carbon footprint, but they can do it faster and even, perhaps, more cost-effectively."

Martin Pike, Project Lead and Senior Construction Engineer, Mace Group

Funding supported multi-disciplinary collaboration and COVID recovery

Bio-based chemical manufacturing shows promise

Biomanufacturer FabricNano won support to develop its technology to improve the sustainability of chemical production. The company was able to show that the technology has promise for a range of bio-based chemical products. The project helped FabricNano to attract further investment and grow its business and jobs.

"Without funding, FabricNano may not have remained solvent today. Our project for bio-manufacturing was relevant to the needs of future FabricNano customers, aligned with our research and development strategy and was a timely injection of funding to support a private market venture capital fund raise"

Grant Aarons, Chief Executive, FabricNano Ltd

We wanted to support collaborative research, but we were also aware of challenges created by the pandemic. Our Building a Resilient Recovery funding opportunity brought funding forward to support innovation-led recovery from the COVID-19 pandemic. It allowed single industry applications in recognition of the constraints imposed by the pandemic. However, many projects recognised the value of multi-industry collaborations and included them.

18 projects were funded with total project costs of £10.5 million

Funded projects focused on establishing long-term viability of domestic supply chains, new markets, new business models, new processes and new products and services.

Details of the projects supported are contained in the Shaping the Future for the Foundation Industries in the UK Resilient Recovery Project Showcase brochure.

In early 2021, a large collaborative research and development funding opportunity was launched to support cross-sector collaboration and improve the productivity and competitiveness of foundation industries. Seven projects were funded, and they collectively covered all six foundation industries.

The projects aimed to further develop technologies to reduce deployment risk and accelerate take-up across industries or develop new technologies that could create a step-change in resource or energy efficiency when deployed in foundation industries.

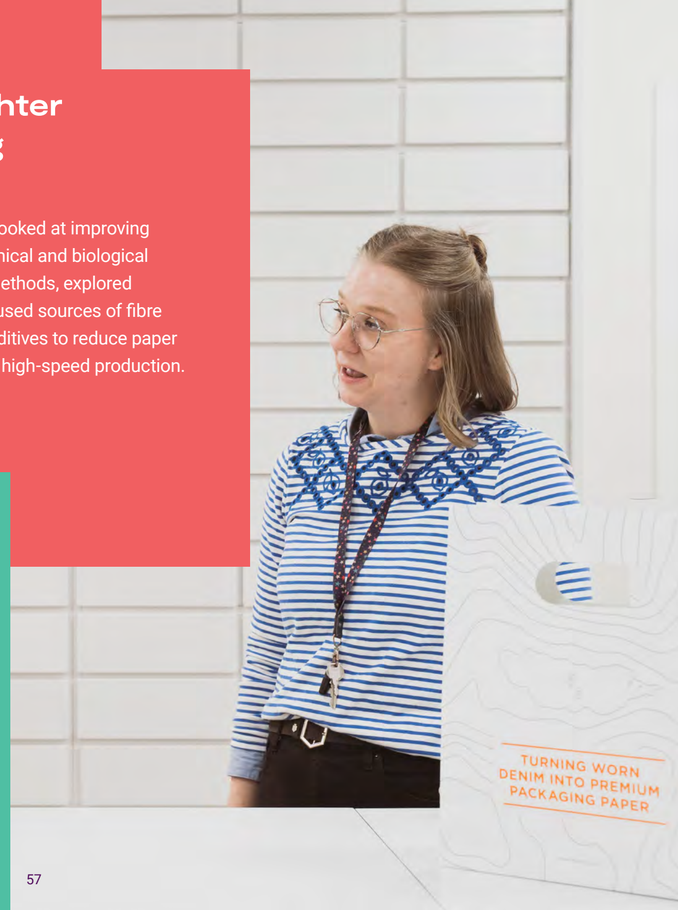
Industry partners investigate lighter and more sustainable packaging

AgriFoodX aims to support innovation in the food supply chain to improve sustainability. It was part of a project to produce lighter, stronger and more sustainable paper and board for packaging. It built on a process called hydrodynamic cavitation that can produce pulp suitable for lighter materials.

The project also looked at improving mechanical, chemical and biological pre-processing methods, explored wasted or under-used sources of fibre and examined additives to reduce paper breakage and aid high-speed production.

> “The support was essential to facilitate the multi-disciplinary industrial collaboration that was required to address an issue of considerable importance to UK foundation industries in the paper and chemicals sectors.”

Prof Graham Bonwick, Director, AgriFoodX Limited



Projects demonstrated industrially relevant technologies

The Transforming Foundation Industries Demonstrators programme aimed to develop future technologies capable of addressing resource or energy efficiency challenges. The focus was on the need for cross-sector collaboration and knowledge transfer between the different foundation industries.

The successful candidates could claim up to £3.5 million to support the development of industrially relevant demonstration and had to attract a significant industrial co-investment. The combination of our funding and the co-investment from industry ensured that the technologies were relevant and could bring long-lasting impact to the foundation industries.

Factory will produce ultra-low-carbon cement

Material Evolution led a

£7.6m project

involving 11 partners to develop and scale up production of carbon-negative cement.

The project built on the company's Mevocrete technology to make cement almost entirely from industrial waste.

"By breaking industry silos, we can foster innovation, establish circular practices, reduce emissions and create new supply chains. Thanks to the funding, we have achieved significant results in both R&D product development and market delivery."

Sam Clark, co-founder, Material Evolution

It successfully established a waste-based supply chain for the cement to be manufactured at the first green cement factory in Wrexham.

Matching business with private investors

Foundation industries have been relatively starved of investment for a long time. Developing and introducing innovative products and processes is often capital intensive, and this represents a high barrier to success.

We have developed programmes to counter this including:

- establishing a community of private investors
- matching innovative business with selected private investors
- supporting sustainable production by spin-outs and start-ups

Community of investors raises awareness

Transformation and innovation in the foundation industries is capital intensive due to the large-scale production processes involved. In many cases in the UK, the industries are operating legacy equipment on a continuous basis and have optimised processes over decades. Patient capital investment is needed to scale up the new technologies and processes needed to make significant strides towards more sustainable operations.

We developed a community of more than

50 investors

to raise awareness of innovation in the field and the opportunities for investment. This activity included a workshop bringing these investors together with spin-outs and start-ups to share experience and insights.

Funded businesses matched with investors

The Transforming Foundation Industries Investor Partner programme was established to match new sources of private investment with businesses bringing transformative innovations.

Our initial involvement with investors revealed a strong interest in supporting foundation industries, and that derisking projects through public funding could help to solidify interest. We worked with five investment funds chosen in a competitive process, Clean Growth Fund, HG Ventures, Midven Ltd, Speedinvest Industry and Turquoise International.

The successful companies secured funding from the investor and were then invited to apply for funding from the programme. The combination of funding and investors' support and expertise allowed the companies to accelerate transformative innovation to foundation industries.

Seven businesses were funded and shared £4.8 million in funding from the challenge and £20 million from private equity investors as part of the Investor Partner programme. Since then, these businesses are reported to have attracted £100 million in new funding.

Inventor of the zero-emission boiler Tepeo was among seven funded businesses. The zero emissions boiler is a smart system that can store heat at the cheapest and greenest times and save money on a traditional electric boiler.

"With this combined investment of £3 million from our investors and almost £700,000 from UKRI, we've doubled our workforce, purchased vital new equipment, moved to larger premises and are developing our technology so that it's ready for large-scale production. It has supercharged the growth of our business"

Johan du Plessis, Founder and Chief Executive, Tepeo

FIVe helps young businesses to reach market

Vital technologies and processes often do not reach market in the foundation industries because of high barriers to entry and large capital requirements.

Foundation Industries Ventures (FIVe) is a not-for-profit incubator and accelerator formed in partnership with the Foundation Industries Sustainability Consortium to support UK start-ups and spin-outs working on the sustainability of material production.

It provides wrap-around support for companies including:

- refining concepts
- honing value propositions
- providing connections into industry and investors
- grant applications or pitch decks
- strategies for company growth
- intellectual property management
- marketing
- mini-MBA value proposition sprints
- one-to-one coaching
- mentoring
- support for industrial-scale pilots and roadmaps
- access to state-of-the-art equipment in scale-up centres across the UK.

Pictured at a FIVe business development event are:
Charles Phelines of BlueCube, **Sarah Harrold (née Connolly)** of FIVe, **Peter Allen** FIVe partner, **Lucy Smith** of FIVe and **David Ferrant** of BlueCube

FIVe also set up a regulatory science and innovation network (FIVengage), with funding from Innovate UK, to better inform pro-innovation policies, introduce flexible performance-based standards and support the delivery of pilot projects to demonstrate new innovations at scale. The learnings can be seen in two reports, **Regulation and Innovation** and **Regulatory Boundaries for the Foundation Industries**.

A FIVengage workshop and networking event in London brought together innovators, investors and corporate partners.

FIVe ‘helped us understand customers and route to market’

FIVe helped eco-engineering company BlueCube to look at the fit between its business and customer needs and how that could be used to deliver future growth.

Pictured are (left to right) FIVe’s **Lucy Smith** with Cambridge Electric Cement Co-founder **Poppy Brewer** and Biozeroc CEO **Liv Andersson.**

“We were able to evaluate BlueCube and the successes and mistakes we’d made and what we need to do in the future. It helped us understand our customers and routes to market and unearthed the processes we need to go through to get there.”

Charles Phelines, Director, BlueCube

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TFI Challenge Delivering Impact

With thanks

to our advisory group, project partners, investors and challenge team.