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Evaluation of Transforming Foundation Industries Industrial Strategy Challenge Fund

Final Report

SQW

Contents

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Executive summary

1. The foundation industries (FI) – cement, ceramics, chemicals, glass, metals and paper – produce around 75% of all the material in the UK economy and underpin many other sectors such as manufacturing and construction. However, FI are capital intensive and are associated with high consumption of raw materials and energy in production, generating around 10% of the UK's CO_2 emissions. As one of the largest industrial polluters, FI face pressure to reduce carbon emissions. Other common challenges include uneven innovation activity and collaboration across the six sectors, few new entrants with little new competition for incumbents, slow technology adoption to improve resource efficiency, and international competition.

2. In this context, the Transforming Foundation Industries (TFI) Industrial Strategy Challenge Fund (ISCF) aims to transform the UK's FI by making them internationally competitive and help them grow in an environmentally sustainable way. This is through increased innovation, collaboration, and investment, and by developing a 'shared identity' to address common challenges. The programme was allocated £66m over five years (2020-2025) through the wider £2.6bn ISCF. Key partners in delivering the Challenge included: Innovate UK (lead), Engineering and Physical Sciences Research Council (EPSRC), Economic and Social Research Council (ESRC), Innovate UK Business Connect (formerly Knowledge Transfer Network), TFI Network+, and TransFIRe.

3. This report is the final impact evaluation of the TFI Challenge which commenced in January 2024 and was completed in March 2025. It provides evidence of the outcomes and impacts of the programme achieved and expected as a result of TFI, including the extent to which these are additional. The work was led by SQW supported by the Institute for Manufacturing (University of Cambridge), IFF Research, Cambridge Econometrics, and a panel of sector experts: Dr David Brown (Aston University); Dr Nick Kirk (Glass Technology Services); and Stuart Maclachlan Lucideon).

4. The evaluation used a theory-based approach – Contribution Analysis (CA) – to assess the performance of the TFI Challenge. This included the development of a logic model and theory of change to test the extent to which outcomes and impacts occurred as a result of the TFI Challenge. It identified other factors contributing to the benefits reported and the relative influence of the Challenge. The evidence was opened to scrutiny principally through workshops, external experts, client group, and the evidence was further assessed and synthesised against the programme logic model and theory of change to arrive at a plausible contribution of the Challenge.

5. The evidence to inform the CA was collected and analysed through mixed methods, including top-down methods to provide contextual evidence on change in the FI and the innovation landscape, and bottom-up methods to provide evidence on performance, in terms of TFI activities and the programme as a whole. Overall, the evaluation received evidence from over 100 beneficiaries (self-reported). This is a strong evidence base to help address the evaluation research questions.

Key findings

Inputs, activities and outputs

6. The Challenge managed its spending appropriately, eventually disbursing £56.6m of the £62.1m (excluding operating expenditure) it was allocated by programme close in March 2025. That date included a one year extension to overcome delays from Covid-19 and allow sufficient time for delivery and for outcomes to arise.

7. Some funds were reallocated from Investor Partnerships (IVP) to collaborative research and development (CRD) and the glass facility, which was facing increased costs due to rising energy and materials costs. Reallocated funds were largely spent. The CRD and IVP portfolios were actively managed: a small underspend occurred where a few projects did not progress as far as expected or were closed early, as is typical of innovation competitions. Sector Strategy also underspent because Innovate UK budget reallocation rules restricted what funds could be used for in the latter part of the programme.

8. The Challenge exceeded, met, or came close to meeting, a majority of its output targets and delivered a number of outputs where no target was set. The programme engaged 182 organisations, of which 151 were businesses, via CRD and IVP. It attracted more private investment than planned, gaining £61.6m for CRD and £99.4m for IVP projects. The key milestone missed was the glass facility being fully operational within the programme lifespan. In practice, setting up such a facility can take a long time.

9. The Challenge was seen to be well-designed and delivered, resulting in good levels of collaboration and diverse projects. Stakeholders and participants welcomed the opportunity represented by a programme dedicated to the FI.

10. Overall, the Challenge performed well in delivering activities and translating these into outputs in line with the programme logic model, in particular through CRD projects and the Investor Partnership projects. The FI sectors, organisations and collaborations supported were mostly aligned with original expectations – the Challenge validated assumptions such as the willingness of industry and academia to engage and collaborate in activities.

11. There were some delays in delivery, for example in full operation of the glass facility, and underspend, which has been reallocated. Given the context for delivery, in particular Covid-19 and rising energy prices, the diverse sectors and organisations involved, and the nature of projects supported, with considerable levels of risk and uncertainty, the Challenge has made good progress.

Key benefits

Outcomes

12. The Challenge made good progress on increasing a sense of shared identity within the FI. This was seen as an important mechanism to change attitudes to collaboration and innovation – encouraging activity to address shared challenges, thereby driving wider, longer-term change within the sector. There was also successful delivery of cross-sector collaboration and engagement with academics on innovation projects. Twenty-eight research organisations participated in a total of 44 CRD projects, with 14 research organisations taking part in more than one project.

13. On key outcomes, the various evidence sources indicate good progress. First, in terms of technology development, the Challenge supported progress in different ways, as measured by paper publications, patents filed, and TRL progression. Second, the Challenge made strong progress on private investment, as evidenced by programme monitoring data (£186m private investment, of which £161m was on CRD and IVP projects) and responses to the beneficiary survey. With additional public sector investment, the Challenge realised £198.2m against a target of £83m. A further £149m was invested in follow-on or related activities, yielding a total of £347m investment.

Impacts

14. Change on impacts was not anticipated until the end of the Challenge in March 2025 or even beyond that date. However, there are encouraging signs of progress on many impacts.

- There is early evidence on increased skills as a result of the Challenge (36/40 beneficiary survey respondents reported upskilled staff).
- There were positive achievements on environmental outcomes, particularly in relation to reduced waste (38% beneficiary survey respondents achieved) and examples of major improvements from specific projects.
- A third of beneficiary survey respondents (11/35) achieved increased turnover (a quarter of turnover increase from exports), over half (20/35) anticipated it; and a third experienced (11/35), and two fifths (14/35) expect improved productivity.

15. The key intended benefit not achieved by programme close was delivery of the glass facility. This was not fully operational by the end of the programme due to issues caused by the Covid-19 pandemic, the UK's exit from the EU, and the war in Ukraine, which had consequences for the construction timetable and costs. Nevertheless, the facility is close to completion, with a staffing structure in place and a membership programme up and running: only the furnace remains to be lit.

16. Overall, there is evidence that the Challenge reduced the economic and technical risks for those directly involved in the Challenge through two key mechanisms. This was through:

- the provision of grants and incentivising investment reduced the financial risk associated with developing innovation / new technologies
- facilitating collaboration brought a range of expertise and experience to bear on shared challenges to find innovative solutions.

17. In summary, the Challenge activities and outputs have been translated into outcomes in line with the programme logic model. The wider economic context is likely to pose issues for the FI after the Challenge closes which means there is some uncertainty about the legacy of the Challenge and whether the early signs of impact will translate into sustained change in the sector.

Additionality and contribution

18. Encouragingly, the Challenge is seen to have played a major role in generating the outcomes and impacts identified. TFI had a medium-to-high level of activity and outcome additionality, as reported by beneficiary survey respondents and Challenge participants interviewed for the evaluation, specifically 95% of beneficiary survey respondents reported full or partial outcome additionality.

- Across Challenge participants, academics reported the highest level of additionality, followed by the glass facility, CRD and IVP project participants (businesses may have more options to pursue different types of activity than academics).
- Relatedly, TFI played a crucial role in realising benefits: more than three quarters of beneficiary survey respondents stated TFI was the critical or an important contributing factor in realising outcomes, alongside other factors (such as availability of people with the right skillset, other innovation partnerships, and availability of knowledge about new technologies).

19. Generally, feedback from both the survey and the consultees indicates that the decision to have collaboration in all aspects of the Challenge was sensible, with the expertise, experience and assets of partners cited as an important contributory factor in realising benefits. The value of contribution is evident across all the workstreams, from CRD projects to academic engagement and the glass facility.

20. The changes in the wider context that have occurred over the life of the programme affected the FI sectors. These included, for example, rising energy costs, disruption in supply chains, access to relevant skills, legacy of the Covid-19 pandemic, sector-specific shocks, and government policy such as an imbalance between energy and resource reduction. These have been significant and have influenced the development of technologies and business benefits.

21. Secondary data analysis on sector-level indicators for the period 2019-2024 provided a mixed picture on key economic and environmental data. This was against a general decline in output and employment in the manufacturing sector, driven by lower-cost competition from overseas and fragmentation of global supply chains. In this context, the evaluation findings can be considered particularly positive. Yet, in terms of the ability of the Challenge to reach its longer-term impacts, the ongoing market and policy context will be crucial to whether organisations continue to pursue sustainable innovations.

Value for money

22. The Value for Money (VfM) analysis involved a balanced assessment of available evidence against the "3Es" (economy, efficiency and effectiveness) of the programme i.e. assessment of the programme's expected ability to deliver outputs, outcomes and impacts in line with the TFI logic model at a minimum cost to the public purse. VfM analysis was underpinned by the monitoring data, beneficiary survey and qualitative insights collected as part of both process and impact evaluations of TFI.

23. Overall, there was positive evidence against all three of the Es. TFI has been economical, efficient and effective in delivering the benefits in line with the programme logic model.

- *Economy* – the TFI programme had a modest budget relative to its scope. CRD funding was competitively allocated (c. 40% rejection rate) to a mix of SMEs and large corporations across FI sub-sectors. Supported projects exceeded targets on attracting additional investment (both UK based and FDI).

- *Efficiency* – the programme met its delivery targets and demonstrated flexibility by reallocating the budget to overcome challenges created by the disruption from the Covid-19 pandemic.

- *Effectiveness* – supported projects have low failure rate (90% are either live or completed), over half of surveyed beneficiaries reported at least 50% of expected short-/medium-term outcomes in line with the TFI logic model. Over two-thirds of surveyed beneficiaries expect to commercialise the technology they developed with TFI support.

Scenario analysis

24. Scenario analysis was used within the evaluation to contextualise the findings, addressing the key question: *'in what ways (if any) has the TFI programme supported the resilience of the Foundation Industries in the UK?'*. Overall, all of the following scenarios are supported and the programme is significantly robust to different futures:

- Scenario 1: Constant flux – there are no periods of stability because of constant external changes affecting the FI

- Scenario 2: Constrained technology flow – the flow of technology is not determined by innovation capacity but by external events
- Scenario 3: Internally driven flourishing – UK government research and industry have solved the problems of material circularity
- Scenario 4: Externally fed flourishing – UK government research and industry have solved the problems of Carbon Capture Use & Storage (CCU&S) production and distribution.

25. The mechanisms by which the Challenge supported the resilience of the FI were twofold. First, the programme has a diverse portfolio, with a range of projects that tackled energy, material and other efficiencies without focussing on a single approach or a singular technology. Second, the programme increased the capacity of the FI to work together.

Overall assessment

26. In our overall assessment, the TFI Challenge has performed very well in achieving its objectives. This is particularly in increasing innovation, collaboration, and investment (public and private). Crucially, there is a greater sense of a shared identity among members of the FI than would have been the case otherwise. Other impacts such as the adoption of innovations/technologies, improved business performance and reduction in carbon emissions were expected to be achieved beyond 2025 but there is already evidence that these are emerging.

27. Importantly, the observed outcomes (achieved to date and future) are additional, highlighting the value of the Challenge. There are other factors contributing to the benefits, but the Challenge is considered the critical or contributing factor, as indicated by beneficiaries and stakeholders.

28. Key to achieving benefits (to date and in the future) has been public and private funding to de-risk projects, the collaborative nature of CRD projects, the flexibility shown by the Challenge in responding to circumstances and the engagement with industry early on in the life of the Challenge and thereafter. Importantly, TFI has been economical, efficient and effective in delivering the benefits, especially in a challenging wider economic context – the Challenge has supported the resilience of the FI in the UK.

29. Finally, the table below presents the key findings against the specific evaluation research questions. These provide the further detail on the above findings.

Table 1-1: Evaluation research questions – key findings

Research question	Key findings
To what extent and how did the TFI Challenge accelerate and facilitate innovation across the FI?	• TFI has accelerated and facilitated innovation across the FI via a programme comprising five workstreams that involved industry and academics in a range of different ways. • The Challenge has had a positive influence on attitudes to innovation within the FI. It has tipped the risk balance – reducing actual and perceived risk of innovation. Respondents to the beneficiary survey reported a significantly greater willingness to innovate as a result of their supported projects: a larger proportion from the beneficiary survey reported this compared to sector survey firms based on their experience of R&D (68% vs 34%). The consultation (beneficiaries and stakeholders) and case study evidence also points to innovation being accelerated and facilitated across the FI. • Most of the beneficiaries surveyed had progressed from TRL 3 to 5 and nearly all of the CRD participants (and all IVP projects) consulted had progressed their technologies. In terms of patents (a narrow measure of innovation), the programme monitoring data indicates that the Challenge achieved 29 patents, far exceeding the target of 10. Also, nearly half (14/30) CRD businesses consulted and a minority of beneficiary survey respondents (8/40) reported having applied for or secured patents or IP. Furthermore, according to the monitoring data, 64 scientific/academic papers were published. This is supported by the beneficiary survey and consultation evidence from CRD businesses. • The two key routes to driving innovation in terms of technology progression were the CRD competitions and the Investor Partnerships. Data on the CRD participants clearly demonstrates that this innovation activity covered all the FI. The metals sector was the most commonly represented sector (included in 35 projects), followed by ceramics and cement (included in just over 20 projects each). The extent of engagement in, and progress by, projects in these two workstreams suggests that the Challenge successfully de-risked the financial and technical risks associated with innovation in the FI.
To what extent and how did the TFI Challenge accelerate growth of new technology, products and services and fast-growing businesses across the value chain?	• The Challenge has done well in identifying and developing new technologies. However, there is limited progress on commercialisation to date. Most beneficiary survey respondents expect their technology to lead to a commercial product or service in the future. This is expected given the long investment cycles and risky technologies associated with the FI. The survey and consultation evidence indicates that the growth of new technology, products and services is likely to accelerate beyond the lifespan of the Challenge (i.e. beyond 2025).

Research question	Key findings
	• The CRD projects were a mixed portfolio of technologies at different stages but feedback from the beneficiary survey showed: 30% of respondents had tested or developed new 'technology solutions';[1] across those respondents, 57 companies had tested/were testing technologies developed by these projects; 10% of respondents had developed a commercially available new product/service that is in the market; and two thirds of respondents expected their project to lead to a commercial product/service in the future. This was reinforced by consultations with businesses and stakeholders who underlined the complexity of translating technology development into widespread adoption. • A key aspect of the Challenge was to accelerate growth of fast growing businesses across the value chain through co-investment with private equity. This was intended to be achieved through the Investor Partnerships workstream. Through IVP a cohort of private equity companies interested in growing fast growing businesses in the FI was identified. The monitoring data indicated five private equity firms invested in six FI businesses (see below for details on investment), although there were more investors sitting behind the lead private equity firms. The focus of these funded businesses was later-stage sustainable technologies. The consultation evidence suggested that nearly all the businesses will develop a new technology and have developed a commercially ready process. As a result, these businesses expected an increase in their future growth.
To what extent and how did the TFI Challenge increase multi/inter disciplinary research and innovation across the FI?	• The Challenge has increased multi/inter disciplinary research and innovation across the FI through providing concrete opportunities for CRD and industry-academic engagement via TransFIRe, and supporting the development of a sense of shared identity among the FI. • The Challenge has facilitated multi-disciplinary research and innovation via grant-funding to 49 collaborative research and innovation projects.[2] These projects involved multiple organisations and sectors: over half the projects (36/66) involved three or more organisations; two thirds of projects were cross-sectoral (41/66); and a minority (11/66) were involved three or more sectors. • Importantly, the Challenge has made good progress on increasing a sense of shared identity across the FI: 44% of beneficiary survey respondents reported an increased sense of shared identity. This compares with 8% for respondents to the sector survey. For Challenge participants, a shared identity was seen as an important mechanism to change attitudes to collaboration and innovation, encouraging activity to address

[1] Programme monitoring data recorded 30 technologies developed with 'proven scalability', against a target of 15.
[2] The other 17 projects in the CRD competitions only involved one sector.

Research question	Key findings
	shared challenges, thereby driving wider, longer-term change within the FI. The greater sense of collective identity is reinforced by a higher rate of recognition of the term 'Foundation Industries' among beneficiary survey respondents compared to respondents to the sector survey (67% vs 15%). • Consultation feedback from CRD participants aligned with the survey evidence: consultees indicated that the experience of the Challenge had generally increased their willingness to work across sectors and with academia.
To what extent and how did the TFI Challenge increase collaboration across the FI including develop closer academic/industry links?	• The Challenge has increased collaboration across the FI including closer academic/industry links. It has had a positive influence on attitudes to collaboration within the FI. Respondents to the beneficiary survey reported a significantly greater willingness to collaborate: 78% of beneficiary survey respondents reported an increased willingness to collaborate compared to 26% of sector survey respondents. Consultees (CRD participants) described how positive experiences of collaboration within projects had changed their interactions with partners and shifted their perceptions of engagement for research and innovation. • The monitoring data illustrates the extent of collaboration within the FI and between industry and academia as supported by the Challenge. This includes TransFIRe, a consortium of 12 research organisations, which was dedicated to increasing industry-academia engagement and Network+, which aimed to build links across the FI and with academia, partly by delivering events and workshops. The CRD competitions also facilitated industry and academic collaboration. Forty-four CRD projects involved a research partner. In total, 27 research organisations took part in CRD projects, with four of these taking part in more than one project. The map shown in Figure 5-4 depicts the wide geographical distribution of both industry and research CRD participants across the UK. • Consultation feedback from businesses and academics was positive about the extent of collaboration driven by the Challenge. The collaborations facilitated by the Challenge, involving multiple sectors, across supply chains, and bringing together competitors, were described as rare opportunities. Consultation evidence from academics highlighted their appreciation of the chance to engage in FI specific activities, particularly those supporting academic-industry collaboration, and the value of links to industry provided by the Challenge and the collaborative community developed by TransFIRe. Overall, links across academia and industry were identified as being much stronger than before the Challenge and potentially leaving a legacy for future engagement.

Research question	Key findings
To what extent and how did the TFI Challenge increase R&D investment in the FI in the UK from private (including overseas) and public sources?	• The Challenge has increased R&D investment in the FI in the UK from private (including overseas) and public sources. Lack of finance for R&D was identified as a key barrier to innovation in the FI. Therefore, the substantial levels of private investment on TFI projects evidenced by programme monitoring data, represents a major achievement for the Challenge: £61.6m on CRD projects, £99.4m on the IVP projects, and £77m FDI. In total, both public and private investment directly for Challenge activities amounted to £198.2m. Further investment of £149m for follow-on or related activities resulted in a total of £347m investment. • The scale of investment, combined with the evidence on the medium-high level of additionality of the programme (discussed in section 7 and below), indicates the Challenge helped to de-risk investment in innovation in the FI. The glass facility received significant funding from both industry (£20m) and other public sector bodies, including the Liverpool City Region Combined Authority (£11.2m in total). • Evidence from the beneficiary survey also indicates Challenge participants have increased private investment in their activities, with over a third reporting this outcome, although investment is on a more modest scale than shown by monitoring data. The combined value of additional investment reported by survey respondents (n=13) was £13.8m, including 10% FDI. A similar proportion of CRD participants consulted for the evaluation reported private equity investment (27%).
To what extent and how did the TFI Challenge minimise environmental impacts by reducing consumption (material resource and energy)?	• The Challenge has demonstrated some progress towards minimising environmental impacts through supporting projects that develop sustainable technologies, materials or more efficient processes. More substantive benefits are anticipated, if adoption of technologies follows and the wider context remains conducive. • Organisations participating in the Challenge reported progress on key environmental metrics, with respondents to the beneficiary survey noting greatest achievement/confidence relating to reductions in waste (10% achieved, 28% expected) and supply chain carbon emissions (reduction in materials used had the fewest responses). • CRD participants consulted commonly reported achieving/expecting reduced waste (73%) and reduced energy usage (60%), although a large proportion of the impacts were expected (47% and 43% respectively). All of the IVP participants consulted believed their technology would lead to reduced carbon emissions if it was widely adopted. Furthermore, independent analysis of key projects by AtkinsRealis

Research question	Key findings
	calculated overall potential to reduce the combined cumulative carbon dioxide equivalent (CO_2e) emissions across all UK-based FI to be up to 25,141 $ktCO_2e$ for the 10 years between 2024 and 2035. • The key issue on minimising environmental impacts is that relevant innovations have to be adopted. Hence the uncertainties in the quantification of greenhouse gas emissions, and the extent of expected environmental impacts compared to those achieved. Many respondents and consultees had only progressed their technology to lab/pilot scale so environmental impacts were modelled rather than measured. In conjunction with the beneficiary survey findings that 60% or more of respondents did not anticipate key environmental benefits, it appears it will take time, favourable circumstances and additional support to improve the sustainability of the FI.
To what extent and how did the TFI Challenge create more jobs in the FI?	• The Challenge was focused on innovation and collaboration rather than job creation but as a result of increased investment, more innovation and an improved sense of identity, it was anticipated that more and skilled jobs would be created in the FI. Ultimately, fewer jobs were created and more retained than anticipated according to programme monitoring data. As a starting point, this is positive and more jobs may be created if the FI become more competitive as a result of successful innovation. • It is worth noting that the programme targets for jobs were high given the immediate focus on innovation, collaboration and investment and the reported figures seem high given employment levels in these sectors. The figures are reported by businesses to TFI and no verification has been undertaken or optimism bias applied. Evidence from the beneficiary survey provides reassurance that the Challenge has made some difference to employment: a third of respondents reported having already experienced increased employment for their business. In total across these respondents there were just over 50 new jobs created (gross). More than half of respondents expect there to be an increase in employment in the next three years, amounting to c. 100 new jobs (gross).

Source: SQW

1. Introduction

1.1 The Transforming Foundation Industries (TFI) Industrial Strategy Challenge Fund (ISCF)[3] is part of the 'clean growth'[4] theme of the UK Research and Innovation (UKRI) Challenge Fund. The foundation industries (FI) – **cement, ceramics, chemicals, glass, metals and paper** – produce around 75% of all the material in the UK economy and are vital for the manufacturing and construction sectors. However, the FI are capital intensive and high consumers of raw materials and energy. They are the largest industrial polluters, accounting for around 10% of the total CO_2 emitted by homes and businesses in the UK.[5]

1.2 The TFI Challenge programme aims to transform the UK's foundation industries by making them internationally competitive, secure more jobs in the UK, and grow the sector by 2025 in an environmentally sustainable way. Specifically, the Challenge has five main objectives:

- accelerate **innovation and new collaborations** across the FI via delivery of a pilot scaling facility and collaborative research and development (CRD) funded projects
- increase **multi/inter-disciplinary research** and innovation across the sectors through supporting development of the FI as a sector
- develop closer **academic and industry links** through programmes dedicated to technology transfer
- accelerate growth of **new technology and fast-growing businesses** across the value chain through co-investment with Private Equity
- increase **Foreign Direct Investment (FDI)** in the UK and **business investment in R&D** via CRD and pilot scaling facility.

1.3 The focus is on innovation, collaboration, investment and development of a 'shared identity' to address common challenges relating to competitiveness and environmental sustainability.

1.4 The programme was allocated **£66m over five years (2020-2025)** through the wider £2.6bn ISCF.[6] This is expected to attract investment of **£83m of co-investment**, potentially providing a total fund size of £149m.

[3] https://www.ukri.org/what-we-do/browse-our-areas-of-investment-and-support/transforming-foundation-industries/
[4] https://www.ukri.org/what-we-do/ukri-challenge-fund/clean-growth/
[5] https://iuk-business-connect.org.uk/materials/foundation-industries/
[6] UKRI Challenge Fund – UKRI

1.5 The key partners involved in delivering the TFI challenge include: Innovate UK (lead), Engineering and Physical Sciences Research Council (EPSRC), Innovate UK Business Connect (formerly Knowledge Transfer Network), TFI Network+, and TransFIRe.

Evaluation objectives and scope

1.6 SQW was commissioned by UKRI to undertake an evaluation of the TFI Challenge. The evaluation commenced in July 2020 and comprised four phases (Table 1-1).

Table 1-1: TFI Challenge – evaluation phases

Phase 1	Report	Period
Phase 1	Evaluation framework	July 2020 – March 2021
Phase 2	Baseline survey of FI when TFI commenced	November 2020 – May 2021
Phase 3	Process and progress evaluation	January 2022 – October 2022
Phase 4	Final impact evaluation	January 2024 – March 2025

Source: SQW

1.7 In undertaking the work, SQW was supported by a team comprising of specialists in undertaking surveys of beneficiaries and the sector, analysis of sector-level secondary data and economic modelling, scenario analysis for the FI, and sector experts across the FI (Table 1-2).

Table 1-2: Study team support

Organisation/individual	Role
IFF Research	Sector and beneficiary surveys at baseline and impact evaluation phases
Cambridge Econometrics (CE)	Sector-level secondary data and modelling sector performance/ economic projections
Professor Steve Evans – University of Cambridge, Institute for Manufacturing (IfM)	Scenario analysis of potential futures for the FI and expert advice
Dr David Brown – Aston University	Advice and support on sector issues within FI
Dr Nick Kirk – Glass Technology Services	Advice and support on sector issues within FI
Stuart Maclachlan – Lucideon	Advice and support on sector issues within FI

Source: SQW

1.8 This report is the final impact evaluation (Phase 4) of the TFI Challenge and provides evidence of the outcomes and impacts of the programme achieved and expected as a result of TFI – and the extent to which these are additional. The focus of this report is on the research questions (RQs) set out below.

Table 1-3: Evaluation research questions

RQ	To what extent and how did the TFI Challenge…
1	Accelerate and facilitate innovation across the foundation industries?
2	Accelerate growth of new technology, products and services and fast-growing businesses across the value chain?
3	Increase multi/inter disciplinary research and innovation across the foundation industries?
4	Increase collaboration across the FI including develop closer academic/industry links?
5	Increase R&D investment in the FI in the UK? Private (including overseas) and public.
6	Minimise environmental impacts by reducing consumption (material resource and energy)?
7	Create more diverse and skilled (technical / managerial / innovation) jobs in the FI?

Source: UKRI and SQW; Note: the order of the research questions has been changed from the evaluation framework

1.9 The impact evaluation implemented the agreed evaluation framework developed in Phase 1. It also took into account the key findings from the previous baseline report, and the process and progress evaluation report (Phases 2 and 3). In addition, it was agreed with UKRI that the evaluation would consider the *economy, efficiency* and *effectiveness* (i.e. '3Es') of the TFI Challenge analysis given the nature and timing of the TFI Challenge.

Report structure

1.10 The remainder of this report is structured as follows:

- **Section 2** outlines the evaluation approach and research methods
- **Section 3** profiles the foundation industries
- **Section 4** presents the TFI programme logic model and theory of change
- **Section 5** assesses the main inputs and activities of TFI including progress against KPIs
- **Section 6** presents the key findings on outcomes and impacts of TFI
- **Section 7** presents the additionality and contribution of TFI
- **Section 8** assesses the value for money (VFM) of TFI in terms of the 3Es
- **Section 9** sets out the findings from the scenario analysis
- **Section 10** sets out the key conclusions and lessons.

1.11 The report is supported by a series of annexes in a separate document:

Table 1-4: Annex Report structure

Annex	Title
Annex A	SIC codes for the FI
Annex B	List of consultees
Annex C	Detail on evaluation methodology
Annex D	Scenario analysis
Annex E	Performance on output metrics
Annex F	Performance on outcome and impact metrics
Annex G	Secondary data analysis
Annex H	Definitions and sources for data and UK forecast assumptions
Annex I	Beneficiary survey results
Annex J	FI sector survey results
Annex K	Case studies

Source: SQW

2. Evaluation approach and methods

Summary

- The evaluation used a theory-based approach (Contribution Analysis) to test the extent to which outcomes and impacts occurred as a result of the TFI programme.
- The approach involved developing a logic model and 'theory of change' (ToC) for the programme, which sets out how inputs and activities translate into outputs, outcomes and impacts, and identifying the contextual factors that could influence progress towards impact, and interim outcomes as well as final impacts.
- The evaluation used mixed methods to collect evidence from a range of sources including primary research with over 100 Challenge beneficiaries (via interviews and a survey of beneficiaries, the latter yielding 40 responses from a sample size of 147, which is a reasonable response rate).
- Contribution Analysis was used to explore the mechanisms driving change and alternative explanations, including factors external to the programme, to refine our understanding of how the Challenge created change.
- In our view, the theory-based approach, combined with the mixed methods and triangulation of evidence from a variety of sources, addressed the challenges posed by evaluation of the programme:
  - the inter-dependent nature of the programme's activities
  - the varying and long timescales to outcomes and impacts
  - multiple external influences that affected the FI sub-sectors
  - the small and diverse set of beneficiaries.
- Overall, the evaluation produced a robust assessment of the programme and a plausible contribution story.

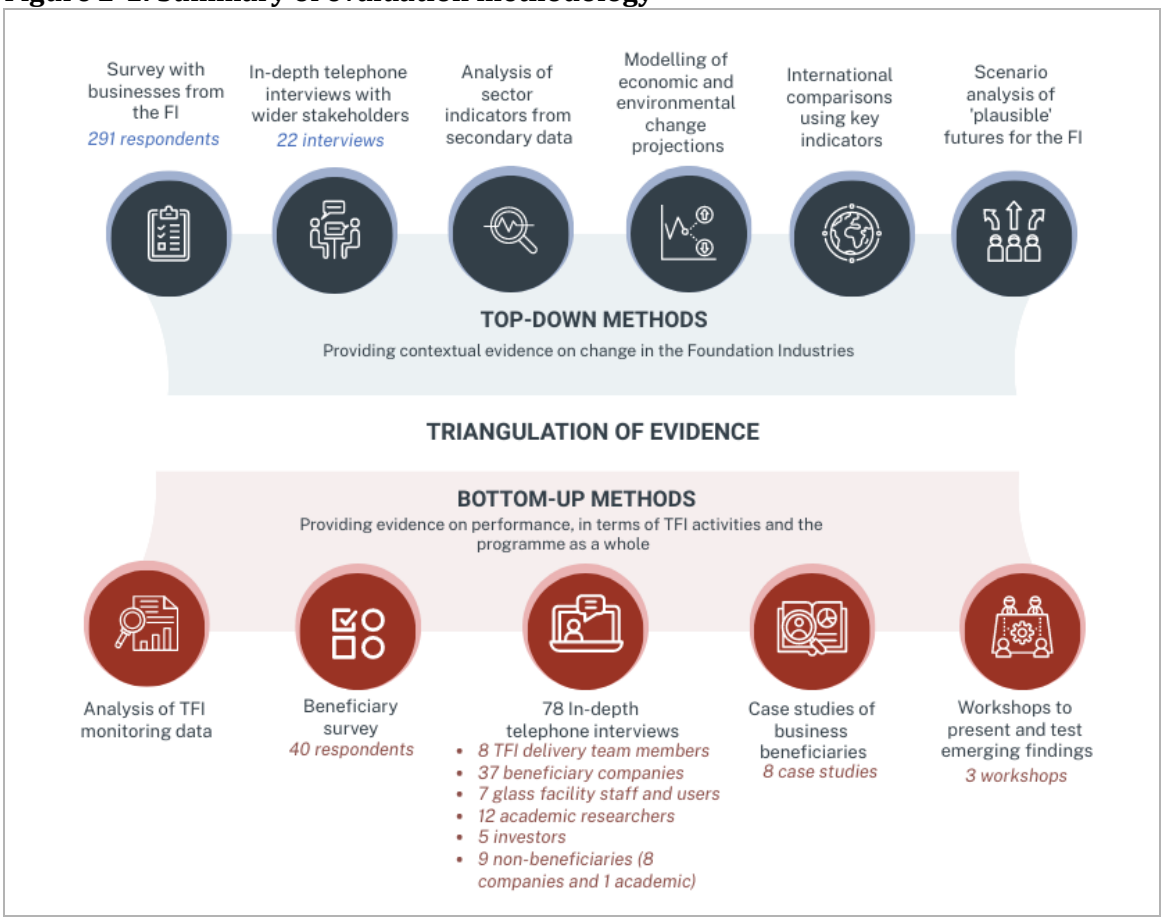
Overall approach

2.1 **We used a theory-based approach – Contribution Analysis (CA) –** to test the extent to which outcomes and impacts have occurred as a result of the TFI programme, in line with the refined logic model and theory of change set out in Section 4. CA also considered other factors which may have contributed to these benefits. Further detail on CA is provided in Figure 2-2

at the end of Section 2 and the Annex Report. Our approach drew on both qualitative and quantitative data. This included a range of top-down methods to provide contextual evidence on change in FI and the innovation landscape and bottom-up methods to provide evidence on performance, in terms of TFI activities and the programme as a whole.

2.2 In undertaking the evaluation, we used the following research methods.

Figure 2-1: Summary of evaluation methodology



Source: SQW

2.3 The evidence was triangulated and analysed against the TFI programme logic model and theory of change as set out in Section 4.

2.4 Table 2-1 presents further detail on some of the top down research methods: analysis of secondary data, modelling of economic and environmental change, performance of the UK FI on key indicators compared to international competitors, and scenario analysis.

Table 2-1: Further detail on selected top down research methods

Method	Summary description
Analysis of sector	• Analysis of secondary data relating to the FI to provide context for TFI. • The indicators were agreed with the TFI Challenge team as part of the development of the evaluation framework.

Method	Summary description
indicators from secondary data	• The analysis covered economic and environment indicators: output (turnover), gross value added (GVA), gross operating profit, employment, labour productivity, R&D, investment, export and import, Greenhouse gas (GHG) emissions intensity.[7] • The data are provided up to the end of 2024. The data therefore provide information on the state of the FI since the launch of the TFI Challenge. They do not provide any information on the performance of the TFI Challenge to date. • See Annex Report for further details including results.
International comparison	• This compares the performance of the UK FI on the following key indicators with the FI Belgium, France and Germany: employment, employment cost, GVA, investment, labour productivity, and turnover. • The analysis does not infer direct causal links between the Challenge and differences in performance between the UK FI and the comparators. • See Annex Report for further details including results.
Modelling of economic and environmental change	• Projections (out to 2040) are provided for the six FI sectors for GVA, employment, labour productivity and emissions. • These projections are derived from CE's forecasting model (MDM-E3) and incorporate historical trends for sectors. • The projections incorporate factors such as the longer-term impacts of Brexit, the price and supply shocks following the war in Ukraine, updated population and migration projections, recovery from Covid-19 lockdowns, and other relevant developments in the economy. • See Annex Report for further details including results.
Scenario analysis	• Scenario analysis examines qualitatively plausible futures for the FI: what will drive the scale and nature of R&D and innovation investment in FI to 2030? • The purpose is to contextualise the evaluation findings: to see whether the TFI Challenge and the evaluation are *resilient* to the scenarios developed at the baseline phase. • The scenario analysis is informed by a review of existing literature, stakeholder interviews, and CE's modelling of economic and environmental change. • Scenario analysis helps to strengthen the TFI programme theory of change and overall contribution story. • See Annex Report for further details.

Source: Cambridge Econometrics; Institute for Manufacturing; SQW

[7] CE also analysed data on FDI and energy intensity but these are not presented in this report due to data issues and interpretation.

Evaluation challenges

2.5 The theory-based approach to the evaluation described above is considered to be a robust way to deal with the challenges posed by an evaluation of the TFI programme. The challenges included:

- The inter-dependent nature of the programme's activities (and complementarities to activities outside of the programme).
- The varying and long timescales to outcomes and impacts.
- Multiple external influences that affected the FI sub-sectors and the programme itself such as rising energy costs, disruption in supply chains,[8] access to relevant skills, legacy of the Covid-19 pandemic, and policy imbalance between energy and resource reduction, which posed difficulties in attributing outcomes to the programme.
- The relatively small amount of public investment in the TFI programme at £66m in comparison to the total size of the six sectors,[9] (which also emphasises the importance of attracting private investment to realise outcomes and impacts).[10]
- The relatively small number of businesses involved in the programme (c. 150), which ruled out statistical analysis to estimate significant effects.[11]
- The nature of the programme (focus on innovation, impacts from individual projects expected in the future) including the small and diverse set of beneficiaries, which made it challenging to create a valid counterfactual/comparison group.[12]

2.6 The strength of the theory-based approach is the development of a 'theory of change' (ToC) for the programme, which encompasses the variation in routes to impact, the contextual factors that may influence progress towards impact, and interim outcomes as well as final impacts. Mixed methods were then used to collect evidence against the ToC to measure progress and assess the role of the programme in generating change. The combination of a range of evidence sources, including programme monitoring data, surveys of beneficiaries and the wider FI sector, and interviews with programme beneficiaries and stakeholders, providing insights on both the internal progress of the Challenge and the wider factors

[8] Partly as a result of the UK's departure from the European Union.
[9] The aggregate size of the FI relative to the amount of public investment has meant that detecting changes in key outcomes and impacts is difficult (within the timeframe for the evaluation).
[10] The programme had a target for £83m co-investment, which included both private and public funds.
[11] Challenge-level quasi-experimental/econometric analysis involving data-linking (based on Difference-and-Differences and Propensity Score Matching) was considered at the evaluation framework stage (and later). However, it was agreed with UKRI that this would not be appropriate/meaningful given the number of businesses engaged and the TFI programme objectives.
[12] The focus of the evaluation was therefore more on evidencing intermediate outcomes i.e. changes in innovation behaviours.

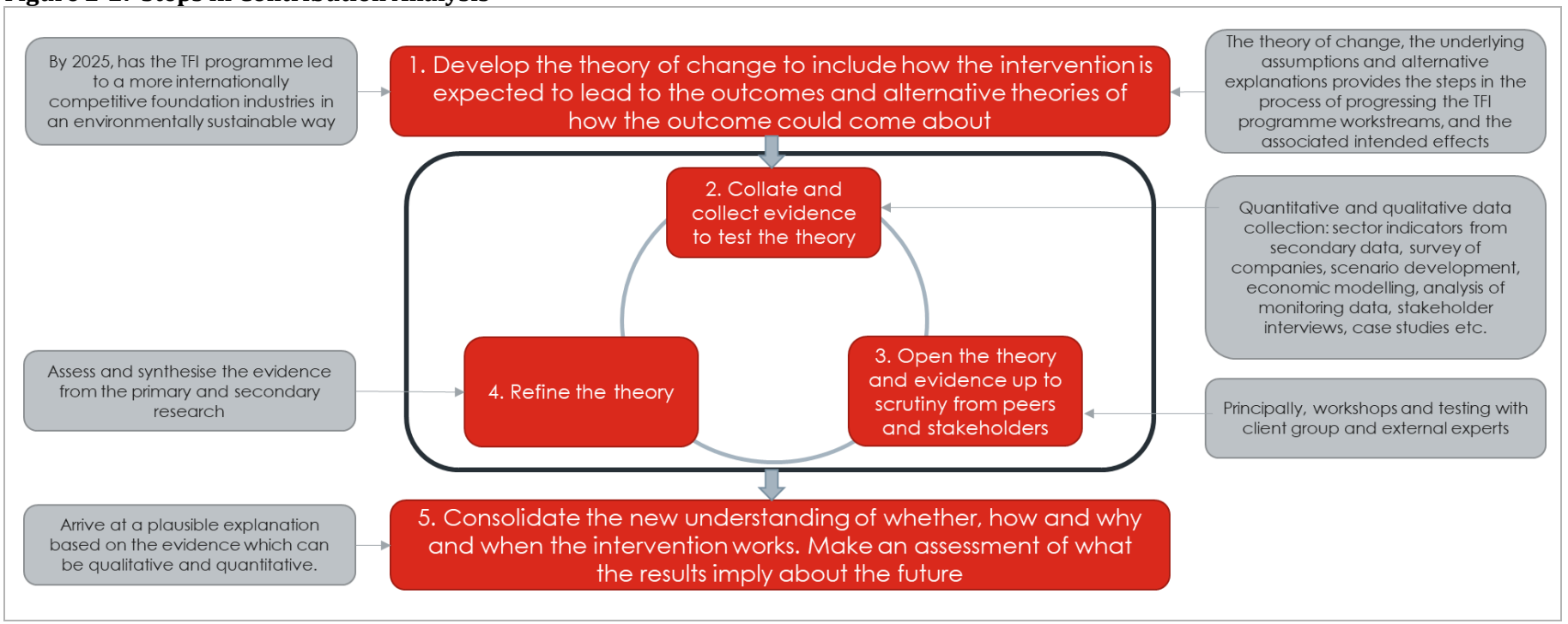
impinging on or supporting that progress, allows us to produce a robust assessment of the programme and a plausible contribution story.

2.7 Specifically on the robustness of the beneficiary survey, this achieved 40 responses from 147 valid contacts[13] (i.e. 27%). This is a reasonable response rate given the number of contacts available. The known beneficiary population is 182 unique organisations (see section 5).[14] This means that there is a 95% chance that the real value is within 11-14 percentage points of the measured value i.e. if 50% of survey beneficiaries report a positive outcome then we can be 95% confident that 39-64% experienced that outcome in the population.

2.8 We note, however, that the samples for specific subgroups of beneficiaries (e.g. by size or programme strand) were below the commonly accepted thresholds for statistical analysis (i.e. below 30 responses). Furthermore, the confidence intervals larger than 10 percentage points may be considered wide, even if higher precision was impossible to achieve given the overall reach of the programme and typical response rates to surveys. Therefore, the degree of imprecision needed to be considered when we interpreted the survey findings and carried out the Value for Money assessment.

[13] Valid contacts refers to contacts with correct contact details (e.g. phone numbers).
[14] 182 unique organisations from Collaborative R&D and Investor Partnerships.

Figure 2-2: Steps in Contribution Analysis



Source: SQW; HMT Magenta Book (2020)

3. Profile of the Foundation Industries

Summary

- There are common challenges associated with the FI sectors. For example, uneven innovation activity and collaboration across the six sectors, few new entrants with little new competition for incumbents, slow technology adoption to improve resource efficiency, and international competition.
- Secondary data analysis on sector-level indicators for the period 2019-2024 undertaken by CE provides context in which the TFI Challenge was delivered. The data provide information on the state of the wider FI from when the TFI Challenge commenced. These data should not be interpreted as explaining the performance of the Challenge itself.
  - **Turnover, employment, and imports** in the FI decreased, whereas **GVA, labour productivity, exports, and investment** (gross fixed capital formation) increased during 2019-2024.
  - **R&D expenditure** in 2022 varied across sectors, in absolute terms and as a percentage of GVA. This was highest in chemicals, followed by metals, and paper and pulp – glass, ceramics, and cement had the lowest expenditure.
  - **Emissions intensity** in the FI increased slightly over 2019-24, while it remained broadly unchanged in manufacturing and the wider non-financial economy.
- Output and employment in manufacturing sector declined, driven by lower-cost competition from overseas and fragmentation of global supply chains.
- Overall, international comparison of the UK FI with Belgium, France and Germany on key indicators (labour productivity, innovation and GVA as a share of manufacturing) provides a mixed picture on relative performance.
- CE's modelling of projections for the FI up to 2040 on economic and energy metrics indicate that **GVA and labour productivity** are forecast to increase. Conversely, **employment and emissions** are expected to fall.

3.1 This section profiles the FI: it provides a working definition of the FI and highlights some of its key features as a sector. This is followed by secondary data analysis relating to the FI to provide background context for the evaluation of TFI. This covers three areas:

- analysis of sector indicators from secondary data for the period 2019-2024

- international comparison of UK FI performance with three selected competitors
- modelling of economic and environmental projections for the FI sectors out to 2040.

3.2 The indicators were agreed with the TFI Challenge team as part of the development of the evaluation framework. The full list of outcome and impact metrics is given in the Annex Report. The secondary data analysis was undertaken by Cambridge Econometrics (CE).

Defining and characterising the Foundation Industries

3.3 The FI can be described as *"manufacturers of core materials that supply other manufacturing and construction firms"*.[15] This evaluation report used UKRI's working definition of the FI based on 2007 SIC codes for the six sectors. The SICs are presented in the Annex Report.[16]

3.4 There are common challenges among the six FI sub-sectors, which support the rationale for a single ISCF Challenge for the FI. There are also important variations between the sectors in terms of current levels of innovation, opportunities and challenges.

3.5 According to the Enterprise Research Centre (2021)[17] and UKRI (2025), the UK's FIs:[18]

- provide essential materials and underpin many other sectors – more than three quarters of FI sales are directly to other businesses
- are energy intensive, experience high energy costs, and face pressure to reduce carbon emissions
- have few new entrants, resulting in low levels of churn and little new competition for incumbents
- have relatively low levels of innovation (this is uneven across the six FI) and do not collaborate as often compared to other sectors
- face constraints in adopting new technologies to improve resource efficiency
- are one of the smallest sectors relative to GDP of the OECD countries, and experience increased international competition.

[15] https://www.ippr.org/articles/strong-foundation-industries
[16] It should be recognised that there are limitations to defining FI by SIC code: the adopted definition is narrow as it is focused on primary producers rather than firms adding value to basic products.
[17] ERC (2021) Innovation Readiness in UK Foundation Industries. An ERC Report for UKRI. https://www.enterpriseresearch.ac.uk/wp-content/uploads/2021/02/ERC-Report-Innovation-Readiness-in-UK-Foundation-Industries.pdf
[18] https://www.ukri.org/wp-content/uploads/2025/02/IUK-130225-ForgingSustainableFuture-CementingChangeIndustriesUnderpinWorld2020To2025Beyond.pdf

Secondary data analysis

3.6 The following sub-sections contain an analysis of secondary data relating to the FI. The purpose of the analysis is to provide sector-level evidence about the wider conditions in which the TFI programme operates, both in terms of the position since the Challenge was announced and to contextualise performance during the evaluation. The following are highlighted.

- The historical data are provided from 2019 until the end of 2024. The data therefore provide information on the state of the FI since the launch of the TFI Challenge. They do not provide any information on the performance of the TFI ISCF to date.
- The data provide **context** for understanding findings from other sources of evidence, and **cannot explain any direct causal links in changes of performance**.
- The data describe the FI as a whole industry and at the sector level. As such, they cannot provide a detailed look at the different types of businesses within the sectors nor indeed of businesses within the supply chains and wider economy that also interact with the FI.

3.7 The wider economic context including trends in the manufacturing sector in the UK needs to be taken into account when considering the performance of the UK foundation industries in recent years. Whilst remaining an important part of the UK economy, output and particularly employment in the manufacturing sector as a whole has declined, driven by lower-cost competition from overseas and the fragmentation of global supply chains.

Methodology

3.8 The historical baseline for the foundation industries examined trends in the five years leading up to the launch of the TFI programme (2014 to 2019).[19] This evaluation report considers the period since the launch of the TFI programme (2019 to 2024). This analysis comprises secondary data gathered from a range of publicly available data sources and estimates, using the most up-to-date data available for each indicator. In some cases, the latest year of data available is 2022. In such cases, the historical data have been extended to 2024 using CE's in-house economic model for the UK, MDM-E3. MDM-E3 is developed and maintained by CE as a framework for generating detailed economic forecasts and analysing changes in economic structure.

3.9 The analysis compares trends across the six foundation industries sectors listed above,[20] the FI in aggregate, the entire manufacturing sector (the FI and the rest of the manufacturing sector, as defined by SIC Section C) and the wider (non-financial) economy (i.e. the overall economy, excluding financial and insurance activities as defined by SIC Section K[21]). While there are clearly important differences between the foundation industries and the wider manufacturing sector, the

[19] SQW (2021) TFI ISCF Evaluation Baseline Report. Data was provided up to end of the FY 2019/20.
[20] These sectors are based on UKRI's working definition of the foundation industries, using 2007 SIC codes, as per the Evaluation Framework (March 2021). The definition is provided in the Annex Report.
[21] SIC Section K is not covered by the Annual Business Survey (ABS) and so has been excluded from comparison for indicators drawn from the ABS.

comparison provides a useful point of reference for assessing the performance of the foundation industries. Any divergences can be explored to understand the reasons for improving or declining performance by the FI and its sectors.

3.10 The analysis covers the following indicators:

Table 3-1: Indicators – sources

Indicator	Source
Turnover	ONS Annual Business Survey
Gross Value Added	ONS Annual Business Survey
Gross Operating Surplus	ONS Annual Business Survey and CE calculations
Employment	ONS Annual Business Survey
Labour productivity	Annual Business Survey and CE calculations
R&D expenditure	ONS Research and Development in UK Businesses, 2022; ONS Annual Business Survey
Investment	ONS Annual Business Survey
Exports and imports	ONS MQ10
Emissions intensity	ONS Annual Business Survey, ONS Environmental Accounts
Employment costs	Eurostat Structural Business Statistics; ONS Annual Business Statistics

Source: Cambridge Econometrics

3.11 The full CE data, definitions and analysis are presented in the Annex Report.

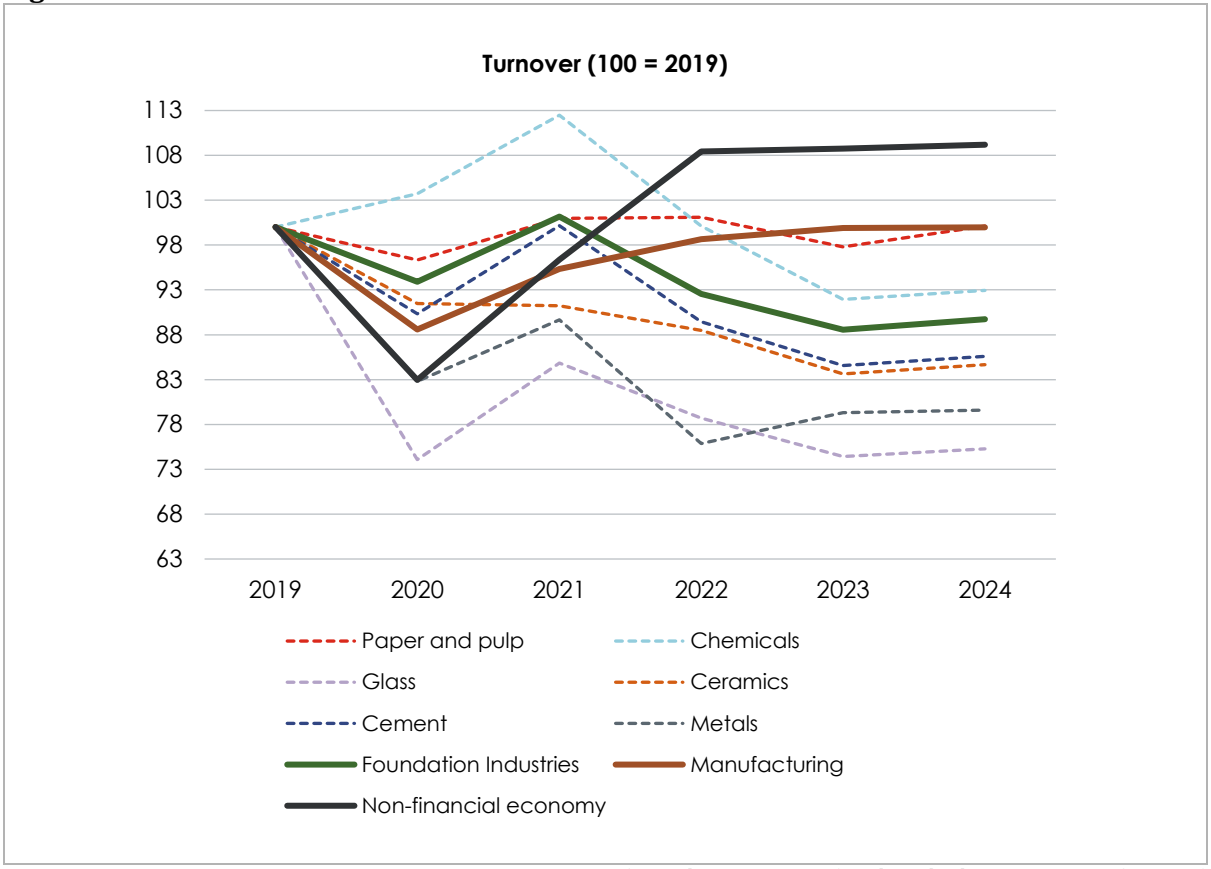
Key performance indicators of the FI, 2019-2024

Turnover, GVA and profitability

- Turnover decreased by 2.1% pa in the foundation industries during 2019-24,[22] while it remained unchanged in manufacturing as a whole, and grew in the wider non-financial economy by 1.8% pa over the same period.
- Turnover in glass decreased the most, by 5.5% pa over 2019-24, and turnover in metals decreased by 4.5% pa, despite GVA in the sector increasing over the period.

[22] Other than paper and pulp, in which there was no change in turnover.

Figure 3-1: Foundation Industries Turnover – Index Base Year 2019

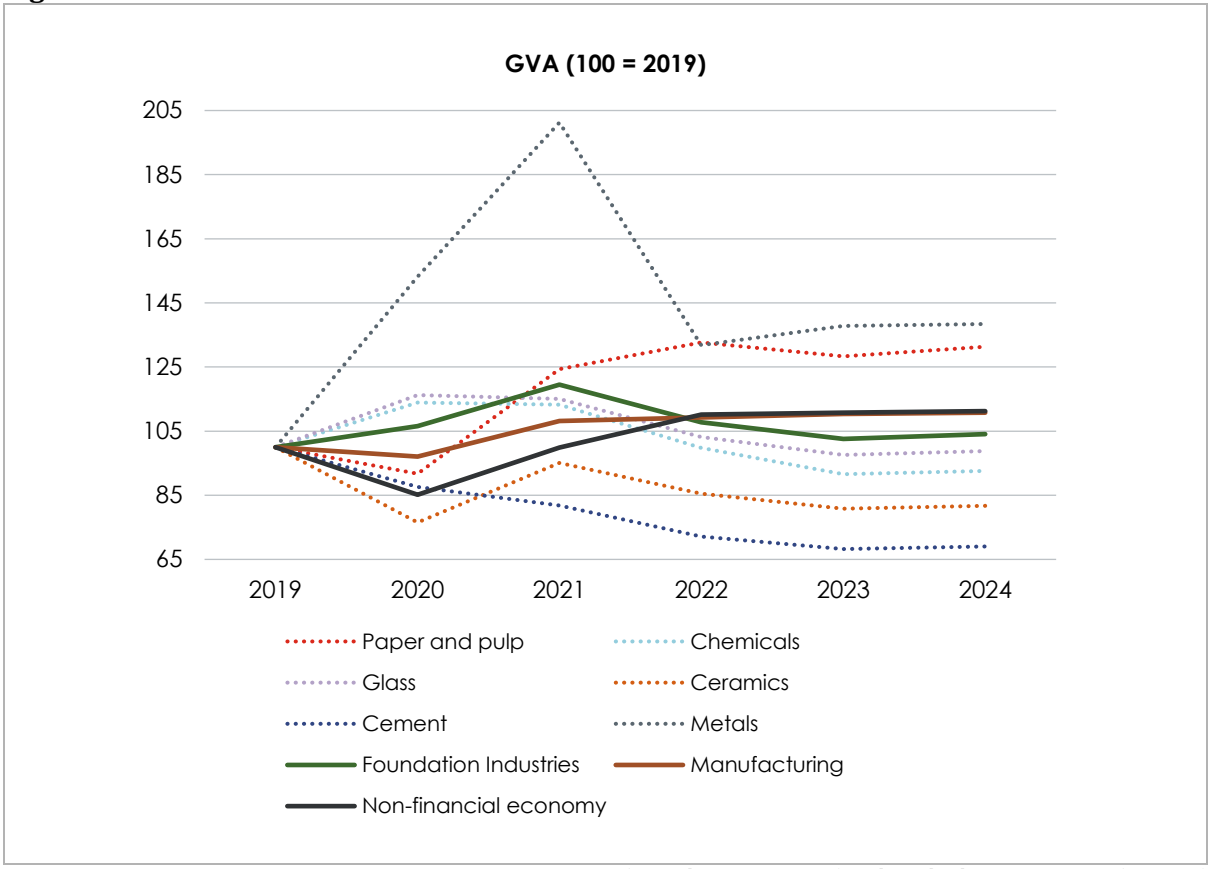


Source: ONS (Annual Business Survey) and Cambridge Econometrics (MDM-E3)

- Foundation industries GVA grew by just 0.8% per year from 2019 to 2024, lagging behind manufacturing (2.1% pa) and the non-financial economy (2.2% pa). Growth was strongest in metals (6.7% pa) and paper and pulp (5.6% pa), while cement saw the largest decline (-7.1% pa).

- Chemicals, the largest sub-sector, declined by 1.5% pa, with ceramics and glass also falling. Metals GVA dipped in 2021–22 due to plant closures and rising costs but recovered in 2023.

Figure 3-2: Foundation Industries GVA – Index Base Year 2019

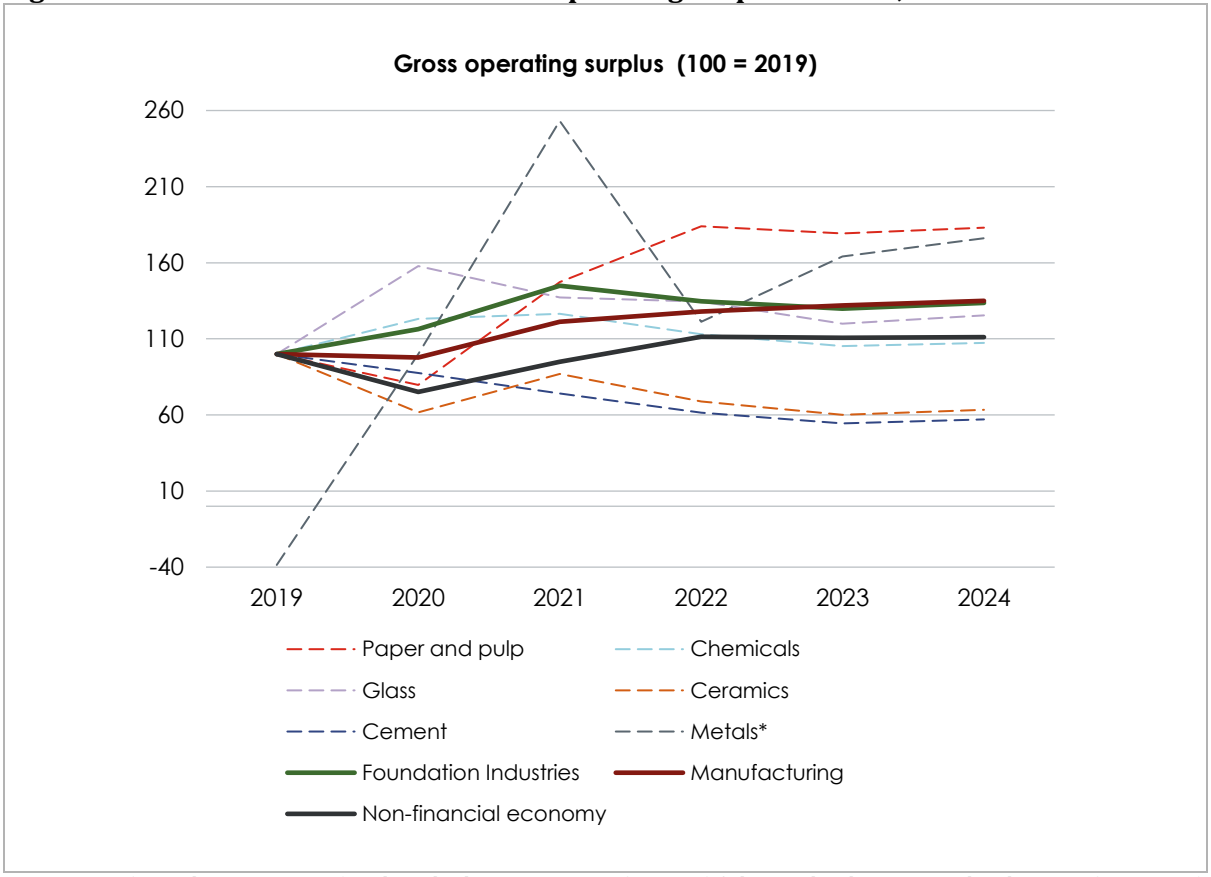


Source: ONS (Annual Business Survey) and Cambridge Econometrics (MDM-E3)

- Gross Operating Surplus (GOS), an indicator of profitability, increased by 6% pa over 2019-24 across the foundation industries, suggesting falling employment costs along with rising GVA. This growth in the foundation industries was nearly three times larger than that of the wider non-financial economy (2.1% pa over 2019-24).

- Chemicals, despite being a major sub-sector, saw a modest GOS growth of 1.0% pa. Ceramics and cement experienced consistent drops of 8.9% and 10.1% pa. GOS grew particularly sharply in metals in this period (indexed from 2020 due to a negative 2019 value) which, despite volatility, had an average annual increase of 15.2%. Similarly, the paper and pulp had strong GOS growth of 12.8% pa, having started from a stronger position in 2019 than metals.

Figure 3-3: Foundation Industries Gross Operating Surplus – Index, Base Year 2019



*Source: ONS (Annual Business Survey) and Cambridge Econometrics (MDM-E3) *The Metals sub-sector is indexed to 2020 (2020 = 100), as GOS in 2019 was negative and not suitable for indexing.*

Employment

- Total employment in the foundation industries sector declined by 0.4% pa over 2019-24, resulting in a loss of 3,000 jobs, compared to a decrease in employment in manufacturing as a whole of 0.8% pa over the same period. In contrast, employment in the wider non-financial economy increased by 0.8% pa over 2019-24.

- The largest increase in employment was in chemicals, which increased by 5,000 jobs over 2019-24. Employment growth in cement and metals remained flat, while it decreased in paper and pulp and glass by around 2.0% pa over 2019-24.

Labour productivity

- Labour productivity measured as real GVA per worker[23] in the foundation industries increased at a slower rate than manufacturing as a whole (1.2% pa compared to 2.9% pa over 2019-24), but it was in line with labour productivity growth in the wider non-financial economy (1.3% pa over 2019-24).

[23] Labour productivity is a common and well established measure of productive efficiency and competitiveness. Labour productivity comparisons are useful to compare the amount of value added per worker between, for example, sectors, countries, and across time.

- There was substantial variation in productivity across the foundation industry sectors in 2024, with chemicals having the highest productivity of any of the other sectors by a large margin (£120,000 GVA per worker in 2024).

- Within the foundation industries, labour productivity increased over the period 2019-24 in paper and pulp, metals, and glass, while it decreased in cement, chemicals, and ceramic. Some of these changes are likely to have been influenced by factors other than just worker behaviour and efficiency, for example, changes in prices of raw materials.

R&D expenditure

- Table 3-2 shows the foundation industries' R&D spending[24] in monetary terms (£m) and as a percentage of the sector's GVA.

- R&D expenditure in 2022 varied across sectors, both in absolute terms and as a percentage of GVA. Chemicals spent the most on R&D, followed by metals, and paper and pulp.

- Glass, ceramics, and cement had the lowest expenditure, indicating a relatively limited focus on R&D compared to the other sectors.

Table 3-2: R&D expenditure, 2022

Sub sector	£m	% of GVA
Paper and pulp	242	5.1
Chemicals	861	6.6
Glass, Ceramics and Cement	167	2.3
Metals	367	7.5

Source: ONS (Research and Development in UK Businesses, 2022; Annual Business Survey).Note: Data presented at a more aggregated SIC level of granularity than UKRI foundation industry sector definitions due to data limitations. SIC correspondence: Paper and pulp - SIC 17; Chemicals - SIC 20; Glass, ceramic and cement - SIC23, Metals – SIC 24.

Investment

- Investment (gross fixed capital formation) in the foundation industries as a whole increased by 3.6% pa over 2019-24, investment in the wider non-financial economy followed a similar trend, though growth was slower.

- Investment in manufacturing as a whole, however, decreased by 1.0% pa over 2019-24, driven by a sharp decrease in 2020 during the Covid-19 pandemic, after which investment has not recovered to pre-pandemic levels.

- The sector that saw the strongest growth in investment over the whole period was paper and pulp (9.8% pa over 2019-24), followed by cement (5.1% pa over 2019-24, supported by a

[24] R&D expenditure includes funding from a variety of public and private sources. See the Annex Report.

strong recovery from the Covid-19 pandemic in 2021) and chemicals (3.1% pa over 2019-24).

- Investment in ceramics and glass, however, decreased by 6.9% pa and 0.6% pa, respectively. Despite a strong increase in investment in metals in 2022, there has not been much growth in investment in the sector since, resulting in investment in metals only increasing by 0.3% pa over 2019-24.

Exports and imports

- There was modest growth in exports in the foundation industries of 1.9% pa over 2019-24. This was driven by exports in metals, which accounted for the largest share of the foundation industries' exports in each year (around 50-75%), and increased by 4.8% pa over 2019-24, while exports in all other sectors decreased over the same period.[25] The highest fall was in ceramics followed by paper and pulp, and then glass.

- Imports in foundation industries decreased by 5.2% pa over 2019-24, with growth fluctuating year-on-year. As is the case with exports, chemicals and metals accounted for the largest share of imports. Growth in imports of cement was the strongest, increasing by 15.7% pa over 2019-24, followed by ceramics and chemicals, which increased by 11.7% pa and 7.4% pa, respectively.

- Of the UK foundation industry sectors, metals had the strongest presence in terms of exports in the global market, accounting for 9-10% of world metals exports in 2022 and 2023. UK chemicals and paper and pulp exports were the second and third largest as proportions of total world exports and remained broadly stable over 2019-2023.

Emissions intensity[26]

- Emissions intensity in the foundation industries increased slightly over 2019-24, while it remained broadly unchanged in manufacturing and the wider non-financial economy.

- Within the foundation industries, there was a slight decrease in emissions intensity in paper and pulp, chemicals and cement, while emissions intensity in metals increased sharply.

[25] Trade figures for the metals sector do not include the precious metals production sub-sector, because trade statistics for this sub-sector are distorted by gold trading (due to London's role as a gold trading hub, UK trade statistics are regularly distorted by gold trading).
[26] The standard definition of emissions intensity is typically measured by dividing emissions by GVA or by GDP, where emissions are the greenhouse gases covered by the Kyoto protocol. Emissions intensity for the overall economy is often calculated by dividing emissions by GDP. When presenting emissions intensity by sector, it is good practice to use GVA because GVA measures the value-added by the sector to the overall economy (GDP is equal to the sum of GVA across all sectors plus product subsidies and minus product taxes). The ONS provides an overview of emissions intensity here.

- Despite decreases in emissions intensities in some of the sectors, all foundation industries still have higher emission intensities compared to manufacturing as a whole and the wider non-financial economy.

Reflections on indicators, 2019-2024

3.12 Examination of the individual sectors reveals their heterogeneity, with contrasting trends in key metrics. For instance, chemicals and paper and pulp are the two largest sectors within the foundation industries in terms of GVA, turnover, and GOS, but while GVA and GOS have increased in paper and pulp, they have decreased in chemicals.

3.13 Metals is characterised by an increase in GVA, GOS, and labour productivity, and is the sector which accounts for the highest share of exports among the foundation industries, despite turnover in the sector having decreased over 2019-24. Among the smaller foundation industries, there was a strong decrease in GVA, turnover, GOS and labour productivity in cement, driven by an increase in material costs.

3.14 The emissions intensity of the foundation industries also increased driven by an increase in emissions intensity in metals, despite emissions intensity decreasing in manufacturing over 2019-24.

Comparison with baseline indicators (2014-2019)

3.15 Table 3-3 compares indicators from the TFI baseline report (2021) which covered the period 2014-2019 with this current report i.e. period 2019-24, as presented above.

Table 3-3: High-level comparison of trends 2014-2019 and 2019-2024

	Growth pa 2014-2019	Growth pa 2019-2024	Trend	Interpretation
Turnover	1.1%	-2.1%	Growing over 2014-19 but falling over 2019-24	Undesirable change, shrinking in recent years
GVA	1.2%	0.8%	Continuously growing but slower growth over 2019-24	Undesirable change, slower growth in recent years
Gross operating surplus	2.0%	6.0%	Continuously growing but faster growth over 2019-24	Desirable change, faster growth in recent years
Employment	1.6%	-0.4%	Growing over 2014-19 but falling over 2019-24	Undesirable change, shrinking in recent years

	Growth pa 2014-2019	Growth pa 2019-2024	Trend	Interpretation
Labour productivity	-0.4%	1.2%	Falling over 2014-19 but growing over 2019-24	Desirable change, positive growth in recent years
Investment	1.3%	3.6%	Continuously growing but faster growth over 2019-24	Desirable change, faster growth in recent years
Exports	-1.1%	1.9%	Falling over 2014-19 but growing over 2019-24	Desirable change, positive growth in recent years
Imports	14.1%	-5.2%	Growing over 2014-19 but falling over 2019-24	Neutral change, UK importing fewer FI goods in recent years
Emissions intensity	-8.0%	6.8%	Falling over 2014-19 but growing over 2019-24	Undesirable change, driven by higher emissions in Metals in recent years

Source: Cambridge Econometrics

3.16 The data provide a mixed picture with some indicators trending in the "right direction" and others in the "wrong" direction, from the perspective of promoting these industries within the UK. One point to note is that a decrease in employment is not necessarily the "wrong" trend, especially if turnover is falling (which it is over 2019-24), as falling employment can contribute to rising labour productivity. In this case, the story is likely more nuanced than just decreasing employment meaning bad outcome.

3.17 For imports, the interpretation is also not straightforward because while the UK FI firms may think it is good that the UK is importing less glass, metal, etc. (less foreign competition for those products), this could be because the demand for those products is generally decreasing in the UK, which would be undesirable. It would only be an unequivocally "good" trend if a decrease in imports meant that the UK is sourcing more of the FI products from domestic producers. We cannot know this for sure from data, but we suspect this is not necessarily true because turnover among UK FI firms was falling over 2019-24.

International comparison

3.18 This sub-section compares performance of the UK foundation industries with those in Belgium, France and Germany. The evidence on international comparison provides additional contextual evidence to inform the evaluation of TFI. It does not infer direct causal links between the Challenge and differences in performance between the UK foundation industries and the comparators.

3.19 The data tables in the Annex Report present performance on the following key indicators by each foundation industry sector in Belgium, France, Germany and the UK in 2022: employment, employment cost, GVA, investment, labour productivity, and turnover.

3.20 Data were collected from the Eurostat Structural Business Statistics and ONS Annual Business Survey for the UK data with 2022 as the latest available year.[27] As the data are only a snapshot of performance in one year, some caution must be applied in interpreting results. Data from a different year may have indicated different respective performance between countries.

3.21 Table 3-4 summarises the UK's rankings among the four countries in terms of three indicators: labour productivity, innovation (as measured by patents) and GVA as a share of manufacturing. The rankings should be considered with caution due to the issues that can affect country performance on the same metrics, but may be indicative of relative performance. We highlight:

- UK ranked second among the four countries in the chemicals sector and third in the paper and pulp, ceramics and cement sectors. Two of the UK's six foundation industries sectors (glass and metals) were the least productive among the countries considered.
- In terms of the number of patents issued, the UK ranked third in five out of the six sectors, with its lowest position being fourth in the metals sector, reflecting that the UK sector lagged in terms of innovation, as measured by patents.[28]
- The UK ranked highest in terms of GVA as a share of manufacturing in both the paper and pulp and ceramics sectors, reflecting that these sectors represent a bigger proportion of the manufacturing economy in the UK than in the other countries. The UK ranked lowest, however, in chemicals and metals on this measure.

Table 3-4: UK ranking in FI sectors, relative to Belgium, France and Germany, 2022

	Labour productivity	Innovation*	GVA as share of Manufacturing
Paper and pulp	3	3	1
Chemicals	2	3	4
Glass	4	3	3
Ceramics	3	3	1
Cement	3	3	3
Metals	4	4	4

*Source: Cambridge Econometrics' calculations. *Number of patents.*

[27] The data are provided to Eurostat by each country's National Statistics Office. In most countries a combination of survey and administrative data is used rather than company returns. The data are available for 4-digit level NACE codes.
[28] Note, there is a case for scaling patents to the relevant national economy for a fairer comparison.

3.22 Overall, the international comparison indicates that, despite some strengths (the paper and pulp and ceramics sectors), there is scope for UK foundation industries to catch up with their peers in competitor countries. This points to particular need for support for the glass, chemicals and metals sectors, although with the caveat that the data represent a snapshot of performance in 2022.

Economic and environmental projections

3.23 This sub-section presents projections for the foundation industries up to 2040 on economic and energy metrics: GVA, employment, labour productivity and emissions. The projections are based on historical data to 2022/2023 (depending on the variable), which includes the TFI programme period. The modelling provides a baseline business-as-usual trajectory of the FI, and does not attempt to estimate potential future major disruptions.

3.24 The modelled projections provide one way of understanding the potential trajectory of the foundation industries over the next couple of decades to 2040. The model is based on past trends and is informed by expert views on likely macroeconomic and market trends. The advantage of the projections is that they provide a quantified description of the potential future performance of the foundation industries.

3.25 The projections suggest that GVA growth in the foundation industries over 2024-40 is expected to be slower than in manufacturing as a whole and the wider non-financial economy:

- GVA in the foundation industries is expected to increase by 0.8% pa over 2024-30, before slowing down to 0.6% pa over 2030-40. Over this period, GVA is expected to grow at a faster pace in manufacturing as a whole and the wider nonfinancial economy.
- Chemicals and paper and pulp stand out as the sectors with the greatest relative increase in GVA over the projection period, driving most of the GVA increase in the foundation industries as a whole.
- Both employment and emissions in the foundation industries are expected to decrease, in line with manufacturing as a whole (for employment) and the wider non-financial economy (for employment and GHG emissions).
- Labour productivity in the foundation industries and manufacturing as a whole, therefore, is projected to increase, despite it decreasing in the wider non-financial economy.
- Labour productivity in the foundation industries is expected to increase at a faster pace than over 2019-24, catching up with expected labour productivity growth in manufacturing as a whole, and outpacing it in the wider non-financial economy.
- The increase in labour productivity is expected to be supported by employment in the foundation industries and manufacturing as a whole decreasing at a faster pace than over 2019-24.

- Employment in glass, ceramics and cement is expected to decrease at the fastest rate across all foundation industries sub-sectors, with labour productivity in those sub-sectors also increasing at the fastest rate, and faster than manufacturing as a whole and the wider non-financial economy.

- GVA, employment and labour productivity growth in metals is projected to be in line with the foundation industries as a whole. All foundation industries are expected to reduce their levels of emissions, with chemicals projected to be the sub-sector expected to decrease its emissions the most.

4. Logic model and theory of change

Summary

- Investment in innovation, skills and technology brought about through the TFI ISCF programme is expected to catalyse cross-sector collaboration and accelerate the development and adoption of new technologies and business models. This, in turn, is expected to increase international competitiveness, drive growth and contribute to the Government's Net Zero target.
- The programme's key inputs are ISCF grant funding (£66m) and industry funding (£83m) invested across five workstreams relating to: scaling innovation, funding industry-led innovation, university technology transfer, networking across the FI and late-stage equity finance for SMEs.
- If there is sufficient interest across industry and academia, key outputs should be: establishment of a glass facility, formation of new collaborations, a combined industry and academic programme of work, CRD projects awarded and progressed, and investment in clean technology.
- If those outputs produce relevant technologies and knowledge, change attitudes and behaviours to innovation, and address barriers to adoption of technology, plus contextual circumstances are favourable, the programme should reduce innovation risk, improve business performance and competitiveness, and reduce energy and resource use (this is tested in the evaluation).

Strategic context and rationale

4.1 The foundation industries – glass, metals, cement, ceramics, chemicals and paper – produce 75% of all the material in the UK economy and are vital for the manufacturing and construction sectors. Collectively, FI are valued at £50bn and employ c. 500k people – mainly in industrial heartlands (e.g. Grangemouth, Teesside, east coast of Yorkshire, Merseyside, and the Midlands). FI are capital intensive and are associated with high consumption of raw materials and energy in production.

4.2 The Government's commitment to Net Zero means the UK must accelerate the pace at which it must reduce its emissions.[29] It also underlines the importance of cost-effective policy

[29] The Seventh Carbon Budget - Climate Change Committee

interventions to maximise opportunities for economic growth as the UK transitions to a green economy, whilst not putting businesses at a competitive disadvantage.

4.3 This commitment is pertinent in the context of cost competition from abroad due to larger-scale, lower-cost production and support for innovation.[30] There is therefore an opportunity for a disparate group of six sectors to work collaboratively to address the following common challenges, and to remain internationally competitive and environmentally sustainable.

- **Technical/economic risk:** FI are capital intensive, high cost/risk and have long investment cycles (c. 30 years), which inhibits the development and adoption of new technologies and ability of companies to compete internationally. The technologies and systems in place stifle innovation; the large amounts of capital required make it challenging to present the commercial case for new technology investments (long time to market and high capital expense leads to underinvestment).

- **Information failures:** There is limited access to private finances because firms within FI are unable to provide appropriate information to investors to make the case for investment in FI. In addition, lack of information sharing between the research base and FI firms on innovations prevents them from effectively working together. Similarly, individual firms within each of the six sectors are not aware of cross-sectoral opportunities or the benefits of working collaboratively to address common challenges.

- **Externalities:** There are *negative externalities* in that the FI are the largest industrial polluters. This wider environmental cost may not be fully taken into account by producers, potentially limiting the incentive to modify/ invest in their processes. There are also *positive externalities* – technology advancement within and across FI and other sectors lead to spillover effects. The social returns outweigh the direct economic benefit realised by innovating firms in FI, leading to sub-optimal investment. Thus, intervention is needed to maximise spillover benefits.

4.4 Investment in innovation, skills and technology brought about through the TFI ISCF programme is expected to catalyse cross-sector collaboration and accelerate the development and adoption of new technologies and business models. This, in turn, is expected to increase international competitiveness, drive growth and contribute to the Government's Net Zero target. **The focus of the TFI ISCF is on 'resource and energy efficiency'**, and it aligns with the overall ISCF objectives, particularly:

- increase UK businesses' investment in R&D and improved capability and capacity

- increase business-academic engagement on innovation activities

[30] Industrial Strategy Challenge Fund – Transforming Foundation Industries Business Case, April 2019.

- increase overseas investment in R&D in the UK.

4.5 There is also partial alignment with the objective: increased collaboration between younger, smaller companies and larger, more established companies up the value chain.

Objectives

4.6 According to the Business Case, the overarching aim of the programme is to:[31]

*"**Transform the UK's foundation industries so that they are internationally competitive in manufacturing products vital for the economy in an environmentally sustainable way".***

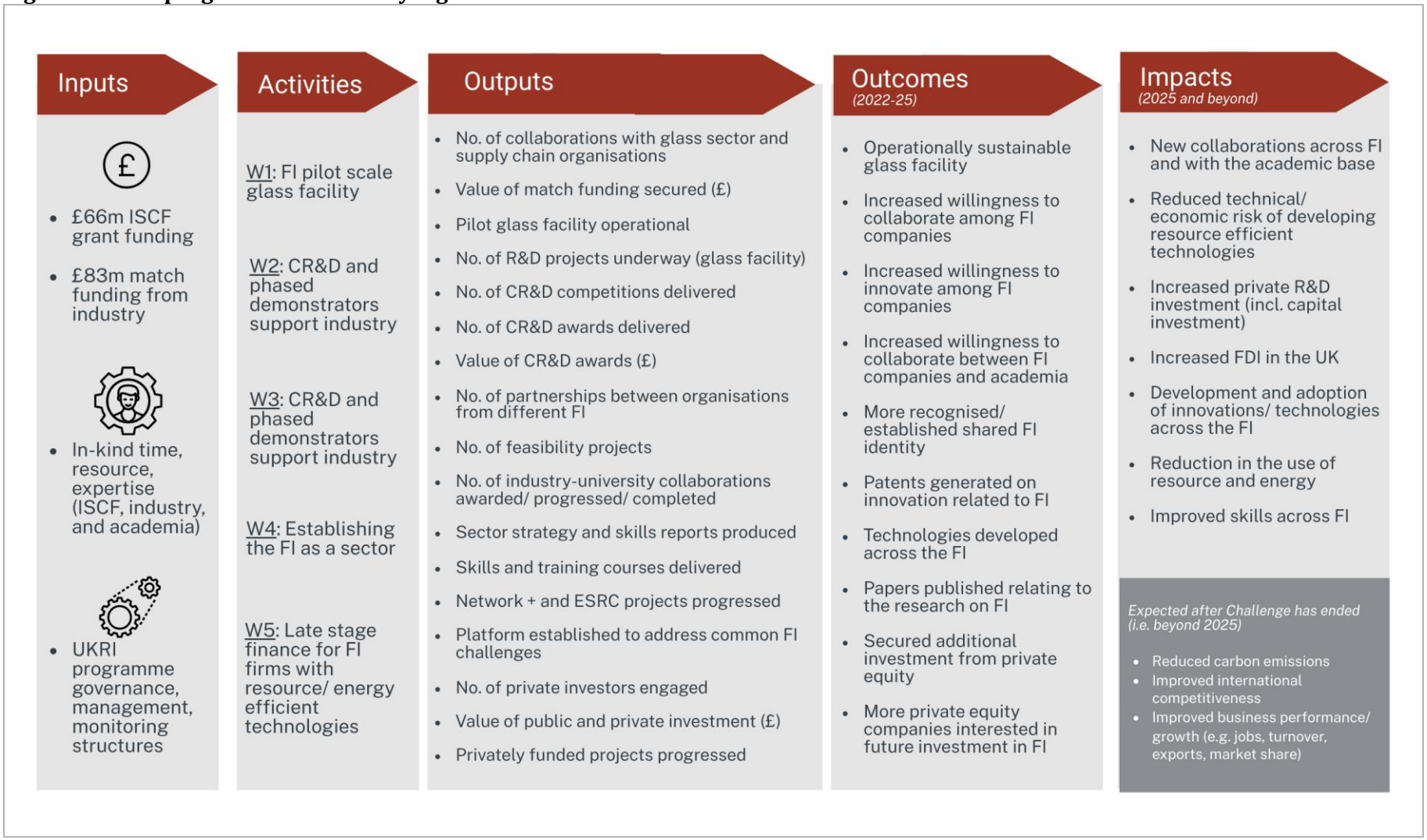
4.7 This is underpinned by five key programme objectives: accelerating innovation and new collaborations; increasing multi/inter-disciplinary research and innovation; developing closer academic and industry links; accelerating growth of new technology and fast-growing businesses; and increasing FDI in the UK and business investment in R&D.

Logic model for the TFI programme

4.8 A logic model for the TFI programme and a theory of change (ToC) is presented below in Figure 4-1. The underlying drivers and assumptions in the logic are set out in the Annex Report. Taken together these describe the relationship between the programme inputs, activities, outputs, outcomes and impacts.

[31] UKRI, (30 April 2019) *ISCF Transforming Foundation Industries Business Case.*

Figure 4-1: TFI programme – summary logic model



Source: SQW; SQW TFI ISCF evaluation framework report (2021). Note: impacts in the box are more likely to be measurable post-evaluation (beyond 2025)

Theory of Change

Inputs and activities

4.9 TFI programme **inputs** are the resources (people, time, materials, funds, etc.) dedicated to its design and delivery. The key programme inputs include ISCF grant funding (£66m) and industry funding (£83m). There is further in-kind time, resource, expertise/knowledge contributions from the ISCF team, industry and academia. The programme delivery team is supported by wider UKRI support functions, as required.

4.10 UKRI programme governance structures and support are available from the Challenge Advisory Group and Programme Board. This adheres to the UKRI standards and the established ISCF Portfolio Management Office delivery structure. Given the multifaceted nature of the programme, resourcing has been reviewed regularly.

4.11 The programme delivers a suite of **activities** across five workstreams relating to:

- scaling innovation
- funding industry-led innovation
- university technology transfer
- networking across the FI
- late-stage equity finance for SMEs.

4.12 A summary of the workstreams and the associated activities is presented in Table 4-1.

Table 4-1: TFI programme – key activities

#	Workstream	Key activities
1	**Glass facility**	• Establishing a £57m open access facility to scale up and commercialise sustainable glass manufacture • Development of a tiered membership scheme and a pipeline of projects • In partnership with St Helens Council, Liverpool City Region and Glass Futures (not-for-profit)
2	**Collaborative research and development (CRD) projects**	• Industry-led CRD projects via Innovate UK competition rounds: project awards from £25k to £2m (see Table 4-2 for details) • Funded projects to undertake FI cross-sector work: develop/scale new technologies, knowledge transfer and adoption • Focus on common resource and energy-efficiency challenges and opportunities, to enable FI to support the resilience and sustainability of the sector (and its supply chains)

#	Workstream	Key activities
3	**TransFIRe**	• EPSRC Research Hub led by Cranfield University, involving 12 research organisations • Connecting academics with companies that can use their technology in industrial settings • Deliver inter-disciplinary research projects with industry that support innovation in energy and resource efficiency • Creation of a Hub bringing together multiple academics with FI-related knowledge • Competition organised to facilitate knowledge transfer from academics to companies, with companies providing match funding
4	**Network+ and Sector Strategy**	• Network+ led by University of Sheffield – focuses on stimulating academic research and collaboration via industry-focused research and wider knowledge sharing and collaboration • Sector Strategy led by UKRI and includes a range of activities focused on community building, developing the evidence base on issues faced by the FI, and future actions to overcome them • Coordination and development of a network across the FI, including delivery of events and workshops, and competition for small proof-of-concept projects, leading to research papers • Supporting skills development in industry, research institutions • Building international partnerships (with India, Germany and Japan)
5	**Investor Partnerships (IVP)**	• Provision of grant funding for businesses to deliver R&D projects, match-funded by private equity investment from selected partners • Projects aim to address resource/energy efficiency in FI industries/supply chains • Selection of investors; funding competition for companies

Source: UKRI

4.13 The CRD competitions are delivered with support from Innovate UK as shown in Table 4-2.

Table 4-2: CRD competitions and projects

CRD competition	Summary
Fast Start	• Projects to support collaboration across FI on common resource and energy efficiency opportunities • Duration 3-12 months; call open October 2019 to February 2020 • Project size £50k to £500k; funded at 25% to 70% of eligible project costs
Building a resilient recovery	• Projects to support an innovation-led recovery from Covid-19 • Duration 3-12 months; Call open August 2019 to November 2020 • Project size £100k to £1m; funded at 50% to 70% of eligible project costs

CRD competition	Summary
Large CRD	• Projects focus on: heat recovery and utilisation; sensors, controls and digitalisation; waste utilisation and symbiosis; and other improvements • Duration 12-24 months; call open January to March 2021 • Project size of £1m to £2m; funded at 50% to 70% of eligible project costs
Small CRD 1 and 2	• Projects to focus on development of new: markets; business models; products and services manufactured by the sector or created by suppliers to the sector; and processes • Delivered in two strands (S1 and S2): S1 offered grants to SMEs and did not require collaboration S2 offered grants to businesses of any size and required collaboration • Duration 3-12 months; calls open June to September 2022 • S1 grants £25k-£75k; S2 grants £75k to £250k • Funded at 25% to 70% of eligible project costs
Demonstrators	• Projects to support a future demonstration of an innovation at an industrially relevant scale • Duration 24 months • Grants of £2.5-£3.5m • Funded at 50% to 70% of eligible project costs
Fast Start Covid-19 and REforMM	• Not part of the original Challenge plan, TFI was asked to run the projects • Projects to support an innovation-led recovery from Covid-19 • Calls did not require collaboration; funded small projects for 5-6 months • Funded at 45% to 100% eligible project costs.

Source: UKRI

Benefits

4.14 The programme's five workstreams of activities lead to **outputs** set out in the logic model. The outputs across each workstream mainly relate to establishing a glass facility, formation of new collaborations, combined industry and academic programme of work, CRD projects awarded and progressed, and investment in clean technology. Furthermore, there are various assumptions which underpin delivery and realisation of outputs:

- there is sufficient interest and engagement in the programme from companies, universities, finance providers, and other stakeholders
- there is appetite to work across the FI and between industry and research
- applications are of sufficient quality and balanced across the six FI sectors

- mechanisms exist for shared learning and knowledge across and within workstreams.

4.15 The outputs for each of the workstreams translate into the **medium-to-long-term outcomes** as indicated in Figure 4-1. These are brought about through several key mechanisms:

- the funding relative to the size of the six sectors is sufficient to make a difference to intended outcomes/impacts
- new and effective collaborations produce knowledge and technologies that are relevant to addressing challenges in FI
- key barriers to adoption and diffusion of technologies are addressed – and firms, universities and other stakeholders have the capacity and skills (innovation and technical) to implement change
- attitudes, behaviours and approaches to innovation change over time – the linkages between workstreams[32] change attitudes towards innovation, and contribute to better diffusion and adoption.

4.16 In turn, the above mechanisms are expected to contribute to **impacts** such as reduced risk, increased innovation and private investment, reduced carbon emissions (via reduced energy and resource use), international competitiveness, and improved business performance.[33]

4.17 In realising benefits there may well be a potential tension between improving economic output (and competitiveness) and reducing energy and resource use – the two may not necessarily be aligned. It is also likely that some projects/companies will succeed and others will fail. This is a normal part of any innovation portfolio: public funding is meant to be targeted at projects that would not otherwise receive funding as investors would deem them too risky but the projects have potential to generate public good. Overriding all of the above is the assumption that the programme timescales (2020-2025) will be long enough to realise outcomes and impacts, especially in a changing context.

4.18 There are alternative and/or complementary explanations of influences on the benefits described in the logic model diagram (Figure 4-1).

- Wider government policy influences innovation and sustainability, for example incentives to reduce energy use.

[32] For example, there are potential linkages between workstreams 2 and 3 in working on collaborative projects/ sustainability challenges.
[33] The impacts relating to reduced carbon emissions, international competitiveness, and improved business performance are expected to be realised in the longer-term and are more likely to be measurable post-evaluation (i.e. beyond 2025).

- Other relevant programmes accessed by the TFI programme beneficiaries, including from UKRI, Innovate UK, DBT, DSIT, etc. make attribution of outcomes and impacts (e.g. changes in competitiveness and reduced carbon) to the programme more difficult.

- Sector-specific market conditions such as firm characteristics, market structure, regulations, and industry-specific shocks influence competitiveness.

- There are wider economic, social and political conditions affecting the FI sectors. Notably Covid-19, Brexit, and energy prices are likely to be significant and to influence the development of technologies and business benefits as well as making it more challenging to isolate the effects of the programme from external shocks.

- International competitors continue to invest heavily to support their respective FI and related sectors (e.g. technology and manufacturing), making it harder for the UK to compete globally.

- There are a range of factors internal to firms that take place (which do not relate to TFI):
  - development and adoption of new technologies
  - technologies and knowledge generated from other/previous R&D (i.e. not TFI)
  - there are collaborations from existing supply chains and networks
  - companies collectively invest in mutually beneficial facilities, e.g. in partnership with universities.

5. Inputs and activities

Summary

- **The Challenge managed its spending appropriately, eventually disbursing £56.6m of the £62.1m it was allocated (excluding opex) by programme close in March 2025.** That date included a one year extension to overcome delays from Covid-19 and allow sufficient time for delivery and for outcomes to arise.

- **There was reallocation of funds from Investor Partnerships to CRD and the glass facility**, which was facing increased costs due to rising energy and materials costs. Reallocated funds were largely spent. The CRD and IVP portfolios were actively managed: a small underspend occurred where a few projects did not progress as far as expected or were closed early, as is typical of innovation competitions. Sector Strategy also underspent because Innovate UK budget reallocation rules restricted what funds could be used for in the latter part of the programme.

- **The Challenge exceeded, met, or came close to meeting, a majority of its output targets**. It has also delivered a number of outputs where no target was set. The programme engaged 182 organisations, of which 151 were businesses, via CRD and IVP. It attracted more private investment than planned, gaining £61.6m for CRD and £99.4m for IVP projects. The key milestone missed was the glass facility being fully operational within the programme lifespan, although only the furnace remains to be lit. In practice, setting up such a facility can take a long time.

- **The Challenge was seen to be well-designed and delivered, resulting in good levels of collaboration and diverse projects**. Stakeholders and participants welcomed the opportunity represented by a programme dedicated to the FI.

Implications for the contribution story

- The Challenge has performed well in delivering activities and translating these into outputs in line with the programme logic model (in particular through CRD and IVP). The FI sectors, organisations and collaborations supported were mostly aligned with original expectations – the Challenge validated assumptions such as the willingness of industry and academia to engage and collaborate in activities.

- There have been some delays in delivery (e.g. the glass facility) and underspend, which has been reallocated. Given the context for delivery (Covid-19, energy prices, etc.), the diverse sectors and organisations involved, and the nature of projects supported (risk/uncertain), the Challenge has made good progress.

- These findings are an important step in understanding the extent to which we may realistically expect to observe outcomes and impacts (see Section 6).

5.1 This section sets out the inputs into the TFI Challenge, and the activities and outputs it delivered. The section draws primarily on the Challenge's own monitoring data as well as consultations with Challenge participants and staff, and wider stakeholders.

Inputs and activities

5.2 **The Challenge managed its spending appropriately, eventually disbursing £56.6m of the £62.1m (excluding opex) it was originally allocated across five workstreams by programme close in March 2025** (Table 5-1).

5.3 **There was some early reallocation of funding across the five workstreams** as the Challenge actively managed its portfolios of projects. The Investor Partnerships funded fewer projects to a lower value than originally planned because there were fewer appropriate applications than expected. However, these projects were successful in terms of leveraging additional investment, indicating that the Challenge had allocated funding efficiently (i.e. it had not awarded the unspent funds on inappropriate or poor quality projects). The underspend from Investor Partnerships was largely reallocated to CRD competitions and the glass facility. The glass facility received the uplift due to additional costs arising as a result of the effects of the Covid-19 pandemic, Brexit and the war in Ukraine. CRD competitions offered the most flexibility to deliver more activity to meet the programme aims.

5.4 **Once the reallocation of funding is taken into account, all of the workstreams came close to spending their allocation, restrictions permitting.** The glass facility and TransFIRe spent all their allocation. The Sector Strategy workstream underspent by nearly 20% of its allocation because it was the last workstream to be mobilised and was not able to spend everything within the programme timeline due to change in Innovate UK budget allocation rules. The Investor Partnerships and CRD competitions underspent by 5% and 14%, respectively: where a small number of projects did not make as much progress as expected or were closed early and so did not draw down the funding. This level of underspend on innovation competitions is considered to be within the normal range for IVP. The higher underspend on CRD was due to more stringent Innovate UK financial controls on reallocation of funding than for other innovation competitions. Where possible, underspends on CRD competitions were recycled into other competitions (Table 5-2) but this was not feasible in the case of the Demonstrators as this was the final competition. The Demonstrators were the largest projects, hence this resulted in the largest underspend across the workstreams.[34]

[34] Projects from two small competitions were also taken on by the Challenge when wider Innovate UK calls yielded projects that focused on the FI, namely Fast Start Covid-19 and REforMM.

5.5 **UKRI was not the only source of investment in the Challenge. There was substantial investment from the private sector**, notably in the CRD projects (£61.6m) and the IVP projects (£99.4m[35]). TransFIRe also received £3.8m from the private sector. The glass facility received significant funding from both industry (£20m, which included both financial and in-kind contributions) and other public sector bodies, including the Liverpool City Region Combined Authority (£11.2m in total).[36]

5.6 Operating expenditure (opex) over the lifetime of the programme cost £4m, around 7% of the programme value. Opex covered the costs of the TFI team at UKRI (i.e. programme leadership, management and monitoring).

Table 5-1: Challenge workstream funding, £m

Workstream	Original allocation	Revised allocation	Amount spent	Amount of industry funding*	Amount of other public funding
Glass facility	14.2	16.5	16.5	20**	11.2
CRD competitions	29.4	31.5	27.1	61.6	n/a
TransFIRe	4.7	4.8	4.8	3.8	1.1
Network+ and **Sector Strategy****	4.3	4.4	3.6	0.7 (in-kind support for Network+)	0.4 (in-kind support for Network+)
Investor Partnerships	9.4	4.8	4.6	99.4	n/a
Opex		4	4.2	n/a	n/a
Total (excl opex)		**62.1**	**56.6**	**185.5**	**12.7**
Total		**66**	**60.7**		

*Source: SQW based on information from the Transforming Foundation Industries Challenge. *Industry funding includes private Form 1 (contractual investment by companies into projects) and private Form 2 (additional but non-contractual investment on projects) funding. **Includes £14.1m financial and remainder as in-kind contribution.*

[35] There are different definitions of what should be counted as industry match funding. The CRD and IVP projects has specific requirements for how much industry had to invest alongside the project grant. For IVP, investors were asked to provide 60%/70% of the grant value (depending on business size). On this basis, the value of industry matched funding for the IVP workstream needed to be £2.9m. Investors subsequently invested more funds into the projects they were involved in. Including the original matched funding and subsequent investment, the value of industry matched funding was £99.4m.

[36] Note, there was a parallel investment in upgrading scale-up facilities for the FI via the EconoMISER programme. EconoMISER was initiated in January 2023 and awarded £19.5m for Phase 1 and £18m for Phase 2. While the programme was separate to the TFI Challenge, it was run by the same team.

Table 5-2: CRD competition funding, £m

CRD competition name	Revised allocation	Amount spent
Fast Start	2.4	2
Building a resilient recovery	6.7	6.2
Large CRD	7.1	6.4
Small CRD 1 and 2	1.2	1.1
Demonstrators	13.6	11
Fast Start Covid-19	0.2	0.2
REforMM	0.4	0.3
Total	31.5	27.1

Source: SQW based on information from the Transforming Foundation Industries Challenge

5.7 The Challenge was originally scheduled to complete in March 2024 but was extended by a year due to disruption caused by Covid-19 in the early stages of the Challenge. The extension was granted to provide sufficient time for CRD projects to be delivered and to allow more time for outcomes to be realised. Ultimately, TransFIRe, Network+ and the Sector Strategy completed at the original end date of March 2024 but benefitted from the extension by continuing to monitor and report to December 2024. The IVP projects and all the CRD projects also completed by March 2024 with the exception of the large CRD Demonstrator projects, which were allowed an extension to March 2025 to complete delivery. Ramifications from the pandemic and the war in Ukraine also caused delays to the construction of the glass facility, ultimately meaning the full opening (for the lighting of the furnace) was expected in spring/summer 2025, two years later than originally planned. Two of the Demonstrator projects had initially planned to use the furnace at the glass facility and had to make alternative arrangements once it became evident the furnace would not be operational before the Challenge completed.

Table 5-3: Challenge delivery against original dates

Workstream	Timing	Original end date
Glass facility	Full opening anticipated Spring-Summer 2025 (when furnace will be lit)	Summer 2023
CRD competitions	Final project closed 03/2025	08/2024
TransFIRe	April 2021 to March 2024*	March 2024
Network+ and Sector Strategy	April 2021 to March 2024*	March 2024
Investor Partnerships	October 2020 to March 2024	March 2024
CRD competitions	*Completion date*	*Original end date*

Workstream	Timing	Original end date
Fast Start	03/2022	03/2021
Building a resilient recovery	12/2022	04/2022
Large CRD	08/2022	04/2022
Small CRD 1 and 2	07/2023	02/2023
Demonstrators	03/2025	08/2024
Fast Start Covid-19	01/2021	n/a
REforMM	02/2024	02/2024

*Source: SQW based on information from the Transforming Foundation Industries Challenge. *Extended to December 2024 for monitoring and reporting*

Outputs

5.8 The Challenge has exceeded, met, or come close to meeting, a majority of its output targets, and delivered a number of outputs where no target was set.[37] This applies to four of the five workstreams. Only the glass facility reported mixed progress, mainly because it did not become fully operational within the Challenge lifespan due to delays in the furnace being lit. The Challenge engaged a large number of organisations: 182 unique organisations, of which 151 were businesses (via CRD and IVP projects).[38] The Glass Futures membership scheme gained 48 members.[39] Table 5-4 shows an overall picture of how the Challenge performed on output delivery. Progress against the full set of output metrics is in separate Annex Report.

Table 5-4: Challenge workstream performance on output metrics

Logic model metric name	Achievement against target
Glass pilot scale facility delivered in terms of progress against milestones (W1)	**Mixed progress** 230 supply chain organisations engaged (target 153) 311 training courses delivered / knowledge exchange (target 200) 48 members (target 65) 30 R&D projects in pipeline (target 50) Full opening scheduled spring/summer 2025 (target 2023)

[37] The list of output metrics is drawn from the logic model, which was designed as part of the evaluation framework. The logic model incorporated outputs against which the Challenge had been assigned targets by UKRI but included additional output metrics where these were necessary to the logic of the Challenge. The additional output metrics do not have associated targets.
[38] The remaining 27 organisations were universities, RTOs and a small number of other types of organisations.
[39] Membership included glass manufacturers, users of glass (e.g. Diageo, a beverage company) and academics.

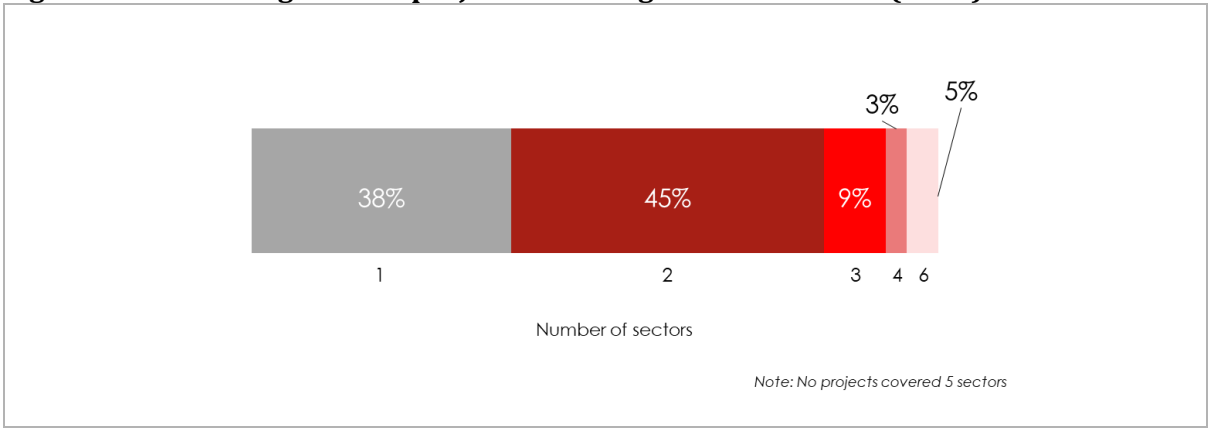
CRD competitions (W2)	**Met or exceeded targets** Delivered 6 competitions (target 6) 66 projects completed or live as of October 2024[40] 182 unique partners supported, of which 151 unique businesses, 27 research organisations[41]and 4 other organisations 49 of the 66 projects were collaborative[42] and involved 165 organisations (against a target of 40 partnerships). 36 of these projects involved a research organisation
TransFIRe (W3)	**Good progress against two main targets** 130 collaborations and partnerships established (target 150) 15 reports published (target 30)
Network+ and Sector Strategy (W4)	**Met or exceeded targets** 44 events (target 20 for Network+) 34 projects (target 20 Network+) 20 reports (target 20 across both) No targets on skills and training courses delivered but over 40 events/workshops and a number of schemes delivered
Number and type of firms funded (W5)	**Six projects completed that met the aim of developing new sustainable technologies for the FI** £99.4m funding from investors (against £2.9m match funding target)

Source: SQW from information provided by TFI Challenge programme team. Orange indicates mixed progress on outputs. Light green indicates good progress that did not quite meet targets. Green indicates targets met or exceeded.

5.9 **The CRD workstream was delivered largely according to plan**, with sufficient projects of sufficient quality delivered to completion across the six planned competitions, supporting 182 unique organisations, of which 151 were businesses.[43] Forty-nine of the 66 CRD projects were collaborative, and involved 165 partner organisations, of which 135 were businesses. The charts below show that two thirds of projects were cross-sectoral (Figure 5-1) and just over a third of projects had five or more partners (Figure 5-2).

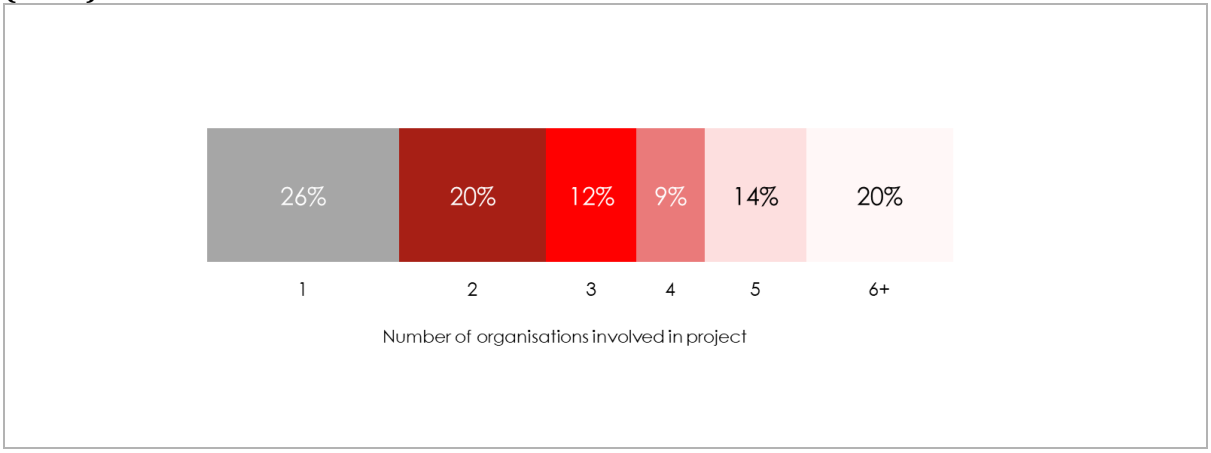
[40] This included 12 Fast Start, 18 Resilient Recovery, 7 Large CRD, 12 Small Strand 1, 3 Small Strand 2, 6 Demonstrators plus 5 REforMM and 3 Fast Start (Covid-19).
[41] Twenty universities and seven research and technology organisations (RTOs)
[42] 5 Resilient Recovery, 7 Small Strand 1, 2 ReforMM and the 3 Fast Start (Covid -19) projects were not collaborative.
[43] Projects from two non-TFI competitions (REforMM and Fast Start (Covid-19)) were added to TFI's portfolio when the successful project applications to these competitions were from the FI.

Figure 5-1: Percentage of CRD projects involving different sectors (n=66)



Source: SQW based on information from the Transforming Foundation Industries Challenge

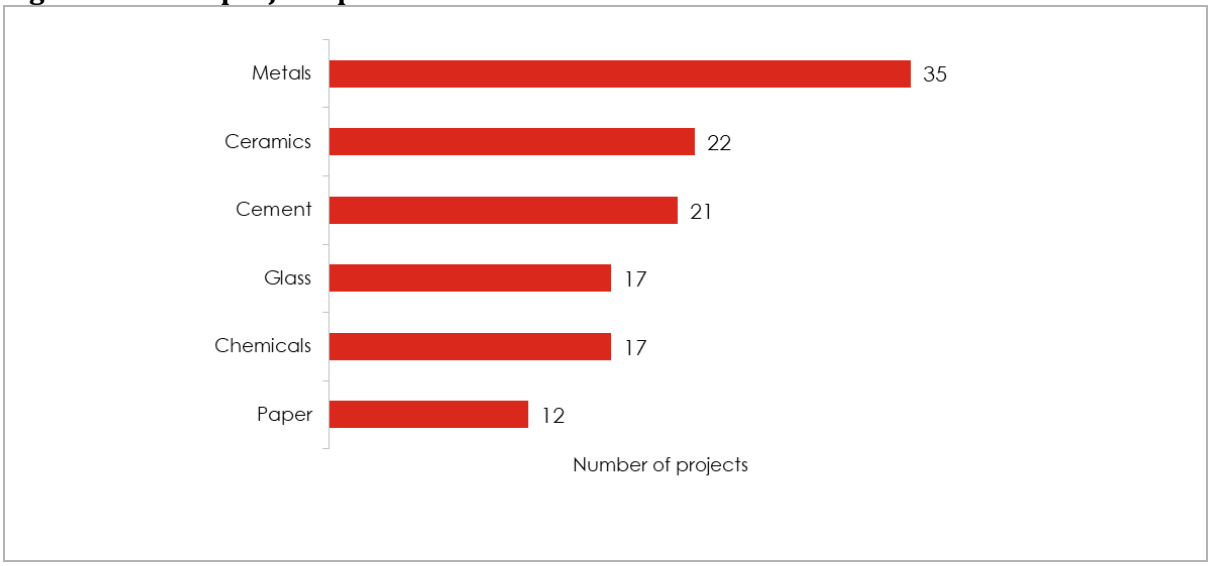
Figure 5-2: Percentage of CRD projects involving different number of organisations (n=66)



Source: SQW based on information from the Transforming Foundation Industries Challenge

5.10 The metals sector was the most commonly represented sector (included in 35 projects), followed by ceramics and cement (included in just over 20 projects each). Paper was the least represented sector (included in 12 projects), which tallies with qualitative feedback that paper was seen as not sharing as many commonalities as the other sectors (Figure 5-3).

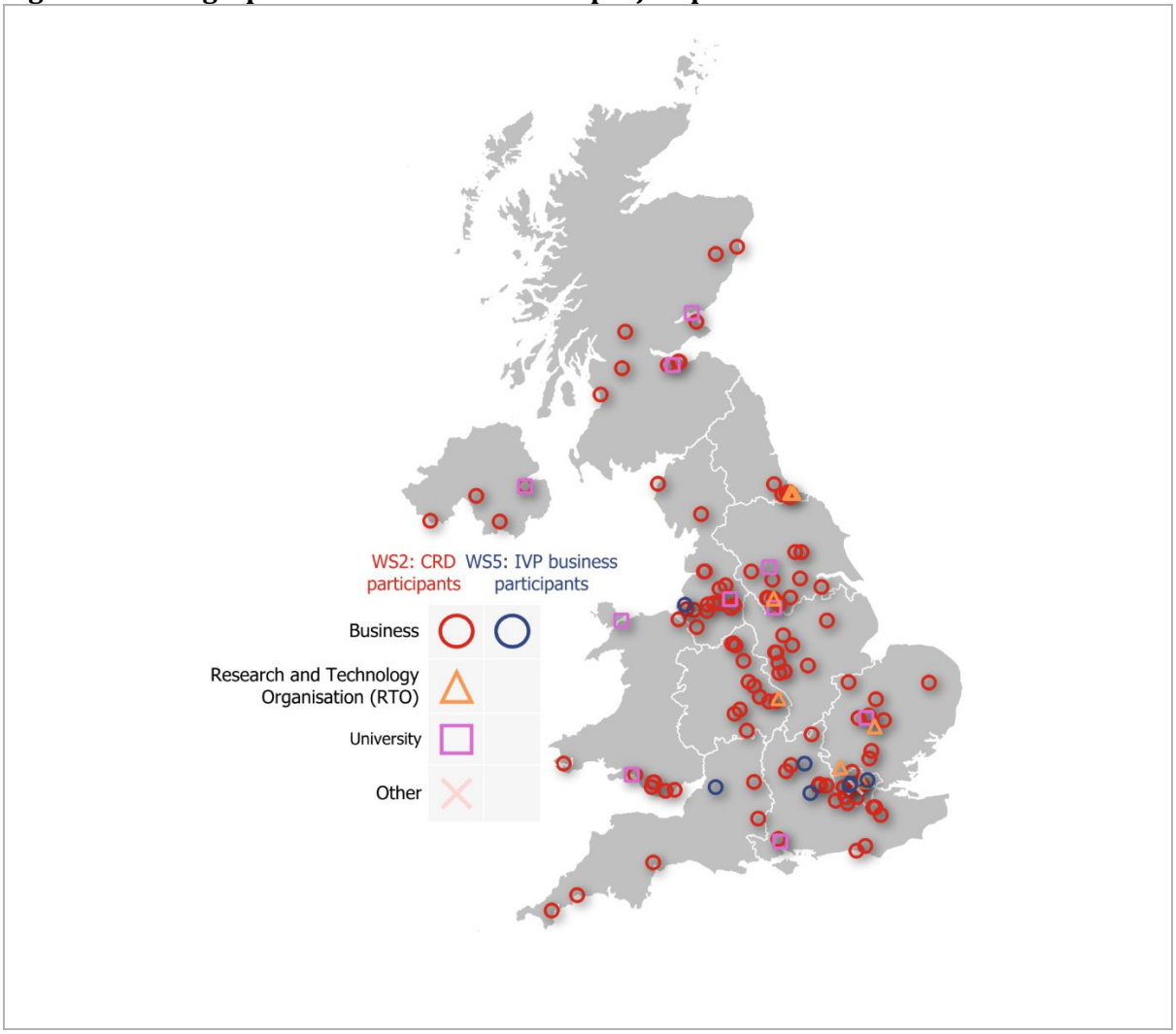
Figure 5-3: CRD projects per sector



Source: SQW based on information from the Transforming Foundation Industries Challenge

5.11 CRD project partners were geographically dispersed across the whole of the UK (Figure 5-4).

Figure 5-4: Geographical distribution of CRD project partners



Source: SQW based on information from the Transforming Foundation Industries Challenge. Other is one partner, HS2 (in London)

5.12 **The Investor Partnership projects delivered on outputs in terms of progressing sustainable technologies for the FI.** While not planned to be collaborative R&D projects, four of the six did involve collaboration with other partners (academic/industrial). There was less geographical distribution of the IVP businesses but it was a small sample.

5.13 **TransFIRe made good progress in terms of establishing academic-industrial partnerships,** generating 130 collaborations and partnerships against a target of 150. It fell slightly short on reports published, 15 against a target of 30. This may be a result of the slow recruitment of academics (identified in the evaluation process report in 2022).

5.14 **Workstream 4, comprising Network+ and the Sector Strategy work, broadly delivered against targets despite a slow start** while mobilisation of other workstreams was prioritised. Network+ over-delivered on engagement activities and research projects. Sector Strategy ran a wide range of skills and training initiatives (although there were no targets for these). The underspend indicates that more could have been delivered if the workstream had been able to mobilise earlier in the Challenge or if Innovate UK budget allocation rules were more flexible.

5.15 Although the glass facility was delayed and is still not fully operational due to the furnace not being lit, it has made good progress on a number of deliverables. For example, training courses and marketing and performed well in engagement with national and international supply chain organisations. However, it has not managed to convert as many of those engagements into formal members as anticipated and it has also under-performed in terms of academic and RTO engagement. The delay in lighting the furnace so the facility is fully operational is likely to have affected its ability to develop a pipeline of R&D projects: it is short of the number needed to demonstrate sustainability to the TFI Programme Board (30 projects against a target of 50 as of October 2024 although, encouragingly, over half of these are cross-sectoral).

Perspectives from participants

Businesses and investors

5.16 **Feedback from CRD and IVP business participants indicated that the Challenge was timely and well-targeted.** Many interviewees described common barriers to innovation that were identified in the Challenge rationale including: struggles to access external expertise and skills; lack of resource to deliver R&D projects independently; and the financial risks associated with innovation. These were also cited by beneficiary survey respondents. IVP investors were more confident than businesses that funding was available for innovation in sustainability but they concurred with businesses that there was a funding gap for scale-up projects. There was widespread appreciation of the opportunity offered by the Challenge to receive funding and support to deliver collaborative innovation projects specifically for the FI and relevant academia.

5.17 **The Challenge was also reported to be well-designed and delivered.** Interviewees observed that the CRD calls and the IVP workstream were tailored to FI businesses, the grant values and match-funding rates were appropriate (i.e. they supported projects with a reasonable level of

ambition), support was helpful, for instance monitoring officers had good sector knowledge, and the programme provided flexibility when projects needed to adapt to changing circumstances.

"Delivery was changed quite a lot. This was largely due to discovering new things throughout the research process. For example, we discovered that working in steel would not be viable and focused more on the potential in glass."

IVP business participant

5.18 Beneficiary survey respondents also valued the monitoring officers: the regular project reviews led by monitoring officers were the most commonly cited aspect of the Challenge that supported projects. This is noteworthy as monitoring can often be seen as onerous. The approach taken by the Challenge monitoring officers appears to be welcomed and beneficial for participants.

5.19 While some interviewees reported that they struggled to deliver all planned activities, this was largely ascribed to unforeseen factors such as increasing costs (typically materials but labour and energy costs also rose over the period) rather than Challenge structures or processes. That said, interviewees thought there was learning for both projects and the programme in terms of planning timelines and contingency, sequencing competitions to have feasibility studies followed by larger grants, and looking ahead to post-project activities at an early stage to maximise progression of technologies. Some businesses were also interested in accessing support to navigate regulation and legislation that may affect their innovation.

5.20 Although the glass facility was not fully operational, companies interviewed considered it to be an important and timely intervention. To date, the facility had engaged with businesses and researchers in various ways, for example by providing advice to members and acting as an RTO partner for companies in other innovation projects or programmes such as TFI's CRD projects and the Industrial Energy Transformation Fund.

"Being involved with Glass Futures has been invaluable for our innovation. They brought expertise we wouldn't otherwise have, and have provided so much information around costs, benefits and adoption processes needed with a new technology."

Business working with Glass Futures

Academics

5.21 Academics were similarly appreciative of the opportunity to engage in FI specific activities, particularly those supporting academic-industry collaboration, and positive about the design and delivery of the Challenge. Those interviewed commented on the value of links to industry provided by the Challenge, the strength of the Network+ team, and the collaborative community developed by TransFIRe, where separate streams of research could feed into each other.

"We managed to ensure that collaboration was a thing and that talking across boundaries was possible. We did some working on industrial symbiosis – getting people to recognise where they had

waste products and also using materials, substituting materials that were waste materials as raw materials was quite successful."

Academic participant in TransFIRe

5.22 Areas for improvement included bringing industrial representatives in earlier to allow more time for relationships to develop, exploiting outputs more effectively at the end of the interventions, and being more flexible with funding where there are delays hiring researchers.

Reflections from programme team and stakeholders

5.23 On design and delivery, the programme team believed that the rationale for the Challenge remained relevant and the underpinning strategy was validated. In particular the focus on collaborations was seen to have yielded positive results, for example through SMEs bringing in new ideas, and the diversity of the Challenge had created opportunities while spreading the risk of innovation. The staging of the Challenge to allow momentum to build and flexibility on plans where necessary, including a one-year extension to compensate for Covid-19-related delays in the first year and a relaxation of the original spend profile rule, were considered to have made delivery more effective.

5.24 From a wider perspective, informed observers agreed with the various participant groups that focused investment in the FI was timely and that the programme approach of different types of activities, collaboration and being demand-led was sensible. There were also views on how delivery could have been more effective, from greater clarity on shared issues across the FI at the outset, for instance the importance of furnace development, planning for sustainability, and factoring in the role of geography in collaboration.

Progress against programme logic model

5.25 The Challenge performed well on delivery of activities and outputs, particularly in terms of delivering successful CRD competitions, a strong Investor Partnerships strand (despite fewer than anticipated suitable applications) and a Sector Strategy strand that met targets despite slow mobilisation and Innovate UK budget rules. Taking a diverse approach, and encouraging collaboration, appear to have supported delivery by attracting a good number and spread of participants into these workstreams, according to stakeholder feedback. Progress on these strands, as well as reasonable progress by TransFIRe and the glass facility, indicates that the Challenge had progressed halfway through the logic model, and many of the delivery assumptions identified in the theory of change have been met, including that there would be:

- sufficient interest and engagement in the programme from companies, universities, finance providers and other stakeholders
- appetite to work across the FI and between industry and research
- appropriate structures in place to meet the operational demands of the programme

- sufficient quality competition applications, balanced across the six sectors
- recognition among businesses and academics of the existence of common challenges across FI and are motivated to seek common solutions.

6. Outcomes and impacts

Summary

- **The Challenge has made good progress on increasing a sense of shared identity within the FI**. This was seen as an important mechanism to change attitudes to collaboration and innovation – encouraging activity to address shared challenges, thereby driving wider, longer-term change within the sector.

- **There was successful delivery of cross-sector collaboration and engagement with academics on innovation projects**. Twenty-seven research organisations took part in a total of 36 CRD projects, with 12 research organisations taking part in more than one project.

- On **key outcomes**, the various evidence sources indicate **good progress**:

  - **on technology development, the Challenge has supported progress in different ways**, as measured by paper publications, patents filed, and TRL progression.

  - **the Challenge has made strong progress on private investment**, as evidenced by programme monitoring data (£186m private investment realised, of which £161m was on CRD and IVP projects) and responses to the beneficiary survey. With additional public sector investment (of £12.7m), the Challenge has realised £198.2m against a co-investment target of £83m. A further £149m was invested in follow-on or related activities, yielding a total of £347m investment.

- Even on impacts, where change was not anticipated until the end or even beyond the lifespan of the Challenge, there are encouraging signs of progress, for example:

  - **increased skills** as a result of the Challenge (36/40 beneficiary survey respondents reported upskilled staff)

  - positive achievements on **environmental outcomes**, particularly in relation to reduced waste (38% beneficiary survey respondents achieved) and examples of major improvements from specific projects (particularly cement-focused innovations)

  - a third of beneficiary survey respondents (11/35) achieved **increased turnover** (a quarter of turnover increase from exports), over half (20/35) anticipate it

  - a third experienced (11/35) and two fifths (14/35) expect **improved productivity**.

- **The Challenge was close to delivery of the glass facility but it was not fully operational by the end of the programme** due to issues caused by the Covid-19 pandemic, Brexit and the war in Ukraine, which had consequences for the construction timetable and costs. Nevertheless, the facility is close to completion, with a staffing structure in place and a membership programme up and running: only the furnace remains to be lit.
- **Overall, there is evidence that the Challenge reduced the economic and technical risks for those directly involved in the Challenge** through a) providing grants and incentivising investment that reduced the financial risk associated with developing innovation / new technologies and b) facilitated collaboration that brought a range of expertise and experience to bear on shared challenges to find innovative solutions. However, the wider economic context for the FI remains challenging, with significant work to be done to improve the sustainability of the FI.

Implications for the contribution story

- The Challenge activities and outputs have been translated into outcomes in line with the programme logic model. As noted above, it has performed well on achieving outcomes, particularly in terms of increasing a sense of shared identity among members of the FI, supporting participants to progress technologies, and generating good levels of private sector investment. There are also indications that these outcomes are beginning to translate into impacts such as reduced waste and increased turnover.
- Key to this performance has been the use of ISCF funding to pull in private investment and de-risk projects, the collaborative nature of CRD projects, and flexibility shown by the Challenge in adapting to the changing context and issues faced by programme participants. The wider context will continue to pose issues for the FI after the Challenge close which means there is some uncertainty about the legacy of the Challenge and whether the early signs of impact will translate into sustained change in the sector.

6.1 This section sets out the performance of the Challenge in terms of outcomes and impacts. The section draws on several strands of evidence including: a survey of CRD beneficiaries; a survey of the wider FI sector; consultations with Challenge participants, staff, and wider stakeholders; Challenge monitoring data; and analysis of secondary data and independent reporting.

Survey samples

6.2 The beneficiary survey respondents were organisations that received funding as part of a CRD funded project. Of the 182 unique organisations funded by the Challenge:

- 144 were valid contacts
- 40 organisations responded to the survey (response rate of 28%)
- 25 of the respondents were from FI businesses and covered all the six FI sub-sectors
- 10 respondents were businesses from adjacent sectors such as other manufacturers and aerospace
- 4 were research organisations (universities/RTOs)
- 1 was a trade association
- More than half (23/40) were small/micro businesses and three quarters (30/40) were UK owned companies.

6.3 The sector survey received 291 responses from FI businesses covering five of the six sub-sectors (no cement companies agreed to be interviewed).

6.4 Full details of the survey samples and responses are available in the separate Annex Report. As noted in Section 3, the 27% response rate is considered in line with industry norms and we can have some degree of confidence that the findings are representative of the whole population (there is a 95% probability that the result for the population would be within 11-14 percentage points of the result for the survey sample).

Overall achievement on outcomes

6.5 The evidence suggests that the Challenge has made good progress on all the key outcomes in the logic model, as summarised in Table 6-1. The one exception relates to the glass facility.

Table 6-1: Overall progress by Challenge on outcomes

Logic model outcome	Progress
Operationally sustainable glass facility	**Success in terms of construction of the facility**, getting the staffing structure in place and beginning engagement with the glass sector, and other interested organisations, including through starting a membership programme. A fully operational facility was not achieved within the Challenge's lifespan due to issues caused by the Covid-19 pandemic, Brexit and the war in Ukraine which had consequences for the construction timetable and costs: specifically the furnace was not due to be lit until summer 2025. Final health and safety checks also need to be undertaken before the facility is allowed to open.

Increased willingness to collaborate among FI companies Increased willingness to innovate among FI companies Increased willingness to collaborate between FI companies and academia More recognised/ established shared FI identity	**Good progress on all attitude metrics:** • 78% beneficiary survey respondents have an increased willingness to collaborate (26% for respondents from wider sector). • 44% beneficiary survey respondents have an increased sense of shared identity (8% for respondents from wider sector).
Patents generated on innovation related to FI Technologies developed across the FI Papers published relating to research on FI	**Good progress on supporting technological progression** in different ways and to different degrees: • UKRI data shows TFI exceeded targets on development of technologies with 'proven scalability' and patents, and published 64 scientific/academic papers. • Majority of beneficiary survey respondents reported TRL progression, a third reported publication of academic papers, a fifth reported applying for/securing patents.
Secured additional investment from private equity More private equity companies interested in future investment in FI	**Strong progress on private investment:** • Attracted private sector investors to invest in the IVP workstream - six projects completed. • £99.4m funding from investors (against £2.9m match funding target).

Source: SQW based on information from the Transforming Foundation Industries Challenge

Changes to attitudes

6.6 **The Challenge has had a positive influence on attitudes to innovation, collaboration, and investment within the FI**. Respondents to the beneficiary survey reported greater willingness to innovate, collaborate and invest as a result of their project than companies from the wider FI sector reported after their own experience of R&D (Table 6-2). It is notable that there was an apparent decline in willingness among sector survey respondents since the baseline in 2021.

Table 6-2: Changes to attitudes, beneficiary and sector surveys* (n=40, n=35, n=291, n=400)

	Beneficiaries	Beneficiaries excluding research organisations and trade associations	Sector respondents	Sector baseline
Increased willingness among FI companies to innovate	68%	77%	34%	44%[44]
Increased willingness to collaborate	78%	83%	26%	30%[45]
Increased willingness to invest	70%	75%	38%	53%[46]

*Source: SQW analysis of beneficiary and sector surveys. *Respondents answered 'a lot' or 'a little' to whether their willingness had changed.*

6.7 It is worth noting that the beneficiary survey respondents were already a more innovative group than the sector survey respondents: nearly two thirds of survey respondents (that were businesses, 16/25) had invested in R&D and/or innovation in the financial year prior to applying to TFI compared to the third of sector survey respondents who had invested in R&D and/or innovation in the financial year up to March 2025.

6.8 The greater willingness to innovate, collaborate and invest among beneficiary organisations than companies in the wider FI sector may be connected to the stronger sense of shared identity among beneficiaries: 44% of beneficiaries reported an increased sense of shared identity compared to 8% sector survey respondents. A fifth of beneficiaries (5, n=25) reported that their experience of the Challenge had not increased their sense of shared identity but 60% (3, n=5) of these already considered themselves as part of the sector. The difference in sense of shared identity is reinforced by a higher rate of recognition of the term 'Foundation Industries' among beneficiary survey respondents compared to respondents to the sector survey (Table 6-3). Roughly the same proportion of beneficiaries and sector survey respondents feel part of the FI when the definition of the sector is explained to them.

[44] Sector baseline sector survey asked: "In the financial year April 2019 to March 2020, did your business introduce any new or significantly improved products, new or significantly improved services, and new or significantly improved processes?"
[45] Sector baseline survey asked: "In the financial year April 2019 to March 2020, did your businesses collaborate with other organisations to develop new products, services or processes?"
[46] Sector baseline sector survey asked: "Did your business invest in R&D and/or innovation in the financial year April 2019 to March 2020?"

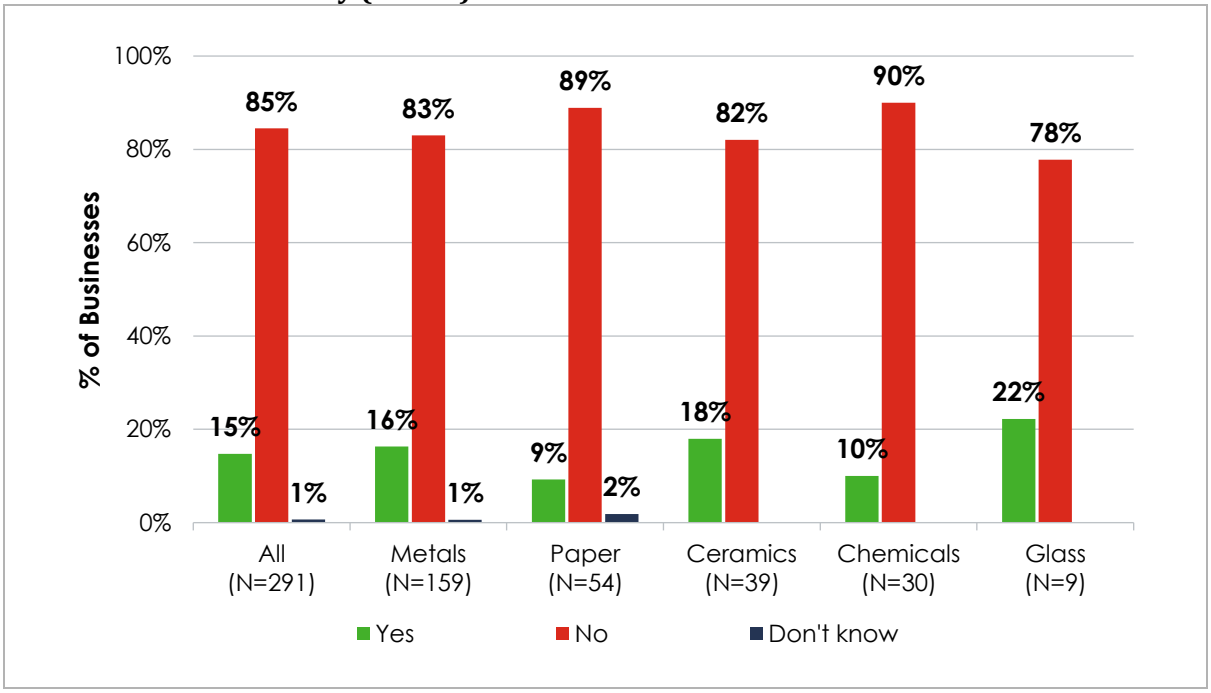
Table 6-3: Shared identity, beneficiary and sector surveys (n=25, n=35, n=291, n=400)

	Business beneficiaries that are part of the FI industries	All beneficiaries excluding research organisations and trade associations	Sector respondents	Sector Baseline
Recognise term 'Foundation Industries'	64%	66%	15%	15%
Feel part of FI	44%[47]	37%[48]	51%	55%
Increased sense of shared identity	44%[49]	43%[50]	7%	Not applicable

Source: SQW analysis of beneficiary and sector surveys.

6.9 It is worth noting that the proportion of firms from across the wider sector that had not heard of the 'Foundation Industries' was fairly consistent across the six subsectors (Figure 6-1). The distribution was similar in the case of firms considering themselves to be part of the FI (Figure 6-2).

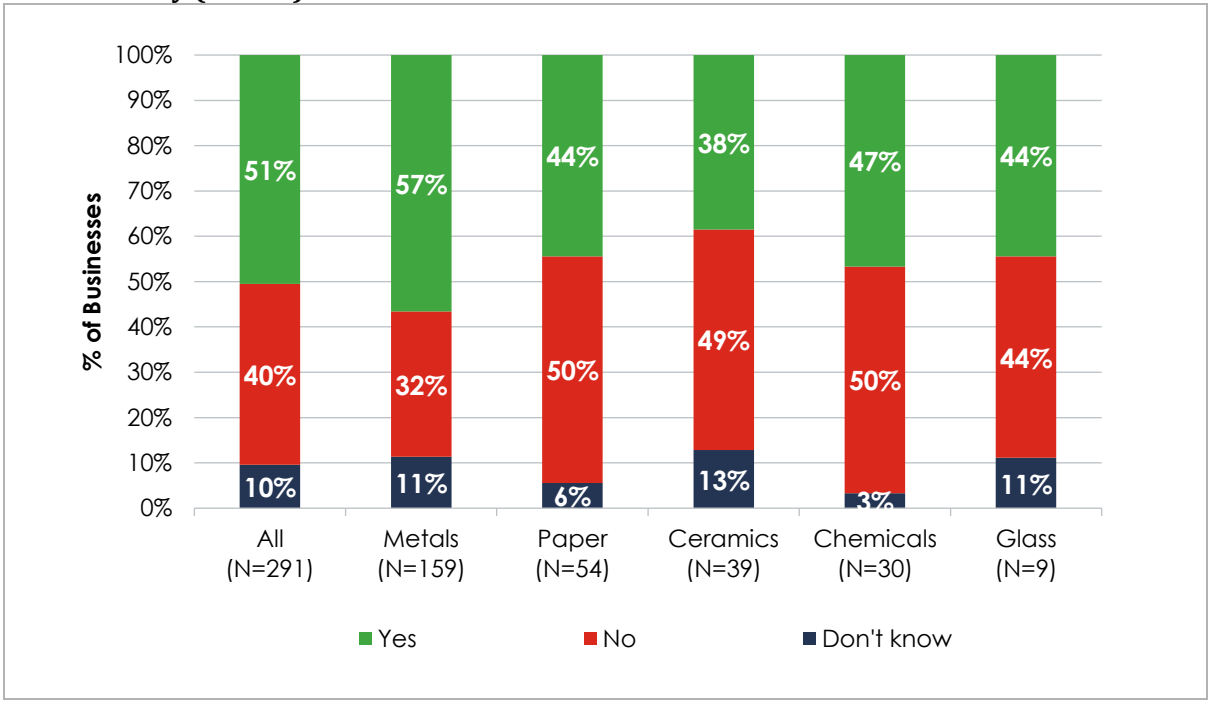
Figure 6-1: Have you ever heard of these sectors being described as 'Foundation Industries'? Sector survey (n=291)



Source: SQW analysis of sector survey

[47] Increases to 69% if 9 respondents who skipped the question are excluded.
[48] Increases to 57% if 12 respondents who skipped the question are excluded.
[49] Increases to 69% if 9 respondents who skipped the question are excluded.
[50] Increases to 65% if 12 respondents who skipped the question are excluded.

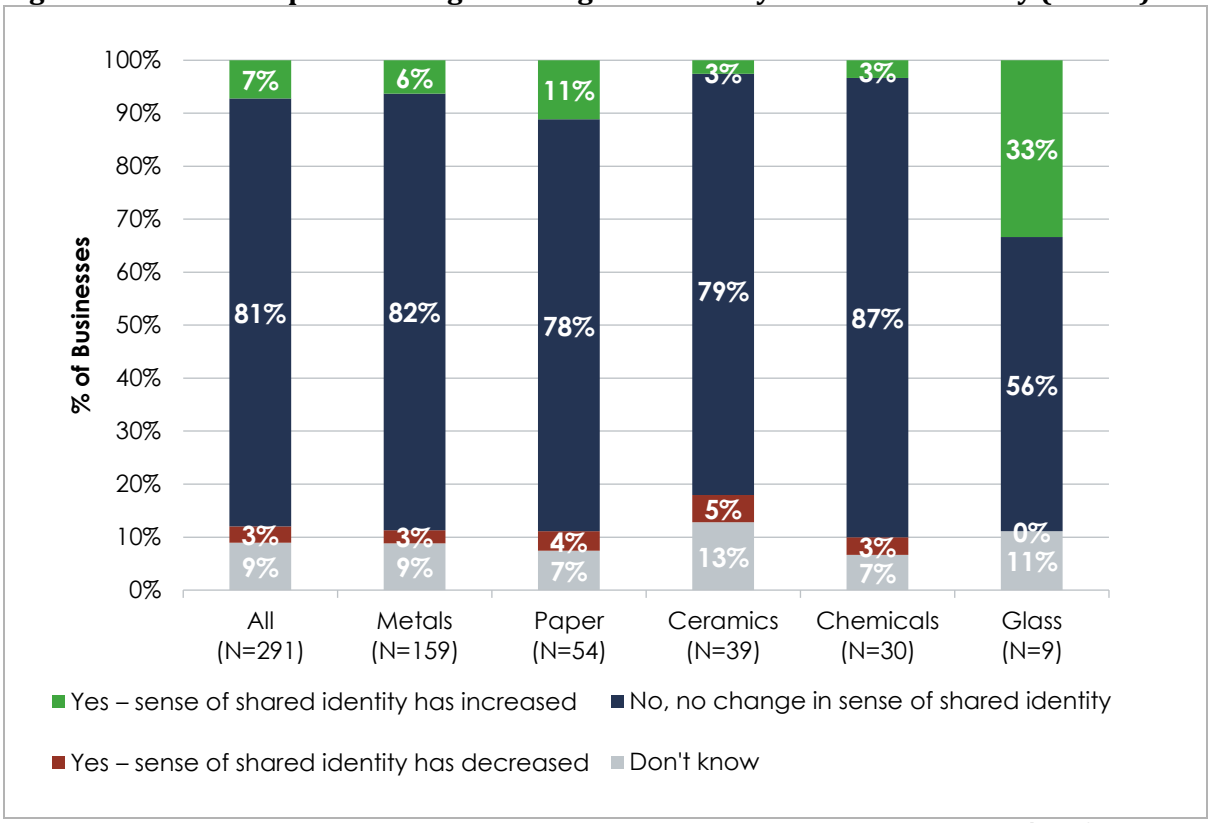
Figure 6-2: Would you consider your business to be part of the Foundation Industries? Sector survey (n=291)



Source: SQW analysis of sector survey

6.10 The small minority of respondents across the wider FI that have increased their sense of shared identity with the FI in the last three to four years is also relatively evenly distributed across the six subsectors with the exception of glass, where a third have an increased sense of shared identity (Figure 6-3). The glass respondents form a small proportion of respondents so care should be taken in interpreting this result but the shift in perception may be a result of the profile of the glass facility, despite it not yet being fully operational.

Figure 6-3: Has this opinion changed during the last 3-4 years? Sector survey (n=291)



Source: SQW analysis of sector survey

6.11 Consultation feedback from CRD participants tallied with the survey evidence: consultees indicated that the experience of the Challenge had generally increased their willingness to both innovate and collaborate across sectors and with academia. Consultees outlined how positive experiences of collaboration within projects had changed their interactions with partners and shifted their perceptions of engagement for R&D.

"We have gained much closer links with other FIs than we expected. There are lots of ongoing discussions that have spawned from this TFI project. We are moving towards more 'industrial symbiosis'. I think there is more recognition of the common issues, and solutions, that FI businesses face. We have really extended our network, and I am quite confident more will come down the line."

CRD participant

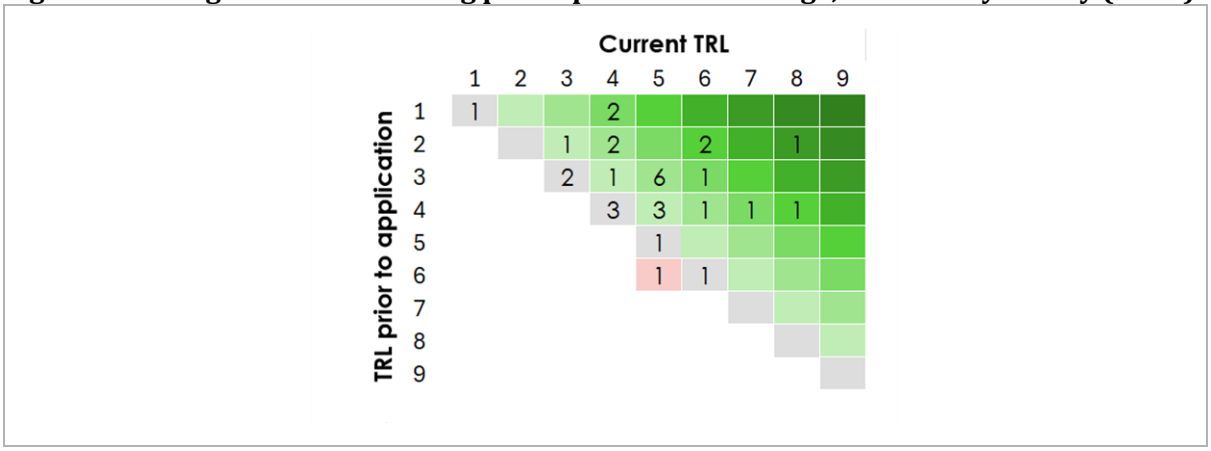
6.12 Together the survey and consultation evidence demonstrate that the Challenge made progress on a key issue: increasing a sense of shared identity was seen as an important mechanism to change attitudes to collaboration and innovation, encouraging activity to address shared challenges, thereby driving wider, longer-term change within the sector.

Achievements on technology outcomes

6.13 The Challenge has performed well on supporting participants to progress technologies. The Challenge's own data show it exceeded its main target on this, recording 30 technologies developed with 'proven scalability', against a target of 15.

6.14 Data from the beneficiary survey offer supporting evidence that the Challenge successfully supported participants to achieve technology progression. The majority of respondents were able to provide a TRL for their technology at the start and at the end of their project progressed at least 2 TRL stages (17/31). The most common progression was from TRL 3 to 5 although one respondent moved from TRL 2 to 8 (Figure 6-4). The diversity of progression is what might typically be expected from an innovation programme investing in a portfolio of risky projects, with the majority of projects making moderate progress, and a few making significant, limited or no progress.

Figure 6-4: Progress on TRL during participation in Challenge, beneficiary survey (n=31)



Source: SQW analysis of beneficiary survey. Darker green squares indicate greater TRL progression. Grey squares indicate no progression. Pink squares indicate regression.

6.15 On a different measure of technology progression, 30% of beneficiary survey respondents reported having tested or developed new 'technology solutions'. This is comparable to the percentage of respondents to the sector survey who reported having tested or developed new 'technology solutions' (34%). However, the beneficiary survey respondents were more innovative than the sector survey respondents: 64% (n=25) businesses that are part of the FI reported having invested in R&D and/or innovation prior to TFI compared to 29% (n=291) sector survey respondents who reported having invested in R&D and/or innovation in the financial year up to March 2025. If beneficiary survey respondents were more innovative than sector survey respondents, they may have had a higher threshold for reporting that they had developed new 'technology solutions' than sector survey respondents.

6.16 Consultation evidence from CRD and IVP participants was strongly positive about technology progression achieved through participation in the Challenge. Ninety percent of CRD participants consulted (27/30) reported technology progress (with Large CRD and Demonstrator projects generally more able to quantify TRL progression and progress closer to commercialisation than participants in other strands) and all the IVP projects had all made technological progress as planned. Of the six IVP projects that completed, consultees from three projects said they had proved feasibility of a process, five consultees said their project will lead to a new technology and three reported having developed a commercially ready process.

""I believe we achieved what we set out to do within this project…. Our goal was to identify a couple of candidate materials to take forward, and we successfully did that by the end of the project."

CRD participant

6.17 A commonly used indicator of technological progression is patents although there has been consultation evidence that this is a blunt measure, with some FI businesses preferring to protect their intellectual property through commercial secrecy, and process innovation[51] often not being subject to patent protection. The Challenge's own data show it has performed better than expected on this measure, recording 29 patents against a target of 10. Nearly half (14/30) CRD businesses consulted and 20% (8/40) beneficiary survey respondents also reported having applied for or secured patents or IP.

6.18 In support of technology progression, UKRI data counted publication of 64 scientific / academic papers (48 within TransFIRe, 26 within Network+) and a third (12/40) beneficiary survey respondents reported publication of academic papers. There was consultation evidence from a majority of CRD businesses (17/30) that they had produced papers regarding their technology.

6.19 Overall, the different evidence sources give confidence that the Challenge has broadly supported technological progression in different ways (papers, patents, TRLs) and to different degrees. The following chapter assesses the extent to which technology development has been accelerated across the FI by the Challenge.

Private investment

6.20 The previous section presented evidence on private investment achieved by the Challenge. In terms of the logic model outcomes, the focus is on private equity investment, which relates to the Investor Partnership projects. The Challenge was successful in attracting private sector investors to invest in the IVP workstream. The aim was to bring in five investors to support ten projects. Ultimately five investors supported six projects to completion. The major success related to the scale of investment in those projects. The initial match-funding requirement was £2.9m (against the £4.8m invested by the Challenge). By the end of 2024, those projects had received £99.4m in funding from investors.

Glass facility

6.21 An operationally sustainable glass facility was a key outcome for the Challenge. Good progress was made in terms of construction of the facility and getting the staffing structure in place. This has enabled Glass Futures as an organisation to begin engagement with the glass sector, and other interested organisations, in a variety of ways including through: starting a membership programme; providing advice and support to members such as on bid-writing; acting as an 'RTO' partner in other innovation projects/programmes such as TFI CRD competitions and the

[51] It is worth pointing out that process innovation is important as a means of improving resource and energy efficiency.

Industrial Fuel Switching competition; and facilitating limited R&D activities on available equipment at the facility.

6.22 There was substantial positive feedback from interviewees ranging from CRD participants to academics to wider stakeholders that the facility is welcomed and there are high expectations of what it will deliver both for the glass sector and the local area as an anchor institution. This is set against a degree of frustration that a fully operational facility was not achieved within the Challenge's lifespan, even with a year's extension. Much of the delay is attributed to issues caused by the Covid-19 pandemic, Brexit and the war in Ukraine, which had consequences for the construction timetable and costs. Delays in installation and commissioning of final equipment, and completion and testing of safety systems, means that the facility is now scheduled to come on line in the summer of 2025 when the furnace will be lit.

Overall achievement on impacts

6.23 The evidence suggests that the Challenge has started to make good progress on all the key impacts in the logic model, as summarised in Table 6-4, although the extent to which the Challenge has influenced the sector beyond those immediately involved in and funded by TFI is less clear.

Table 6-4: Overall progress by Challenge on impacts

Logic model impact	Progress
New collaborations across FI and with the academic base	**Good delivery of cross-sector collaboration and with academics** with positive consultation feedback about the extent of collaboration driven by the Challenge.
Reduced technical/ economic risk of developing resource efficient technologies	**The Challenge reduced the economic and technical risks for those directly involved in TFI** but the scale of the challenges faced by the FI remain significant.
Increased private R&D investment (incl. capital investment) Increased FDI in the UK	**Strong progress on private investment:** • The Challenge's own data show over-achievement on targets for private R&D investment and FDI. • Beneficiary survey data and consultation indicates a good proportion of Challenge participants have achieved increased private investment (third of survey respondents, a quarter of consultees).
Development and adoption of innovations/ technologies accelerated across the FI	The Challenge's own data recorded 12 technologies adopted at scale, against target of 30 and 4 companies have developed a commercially available new product/service that is in the market.
Reduction in the use of resource and energy	**Positive achievements on environmental outcomes**, with over a third of beneficiary survey respondents reporting reduced waste and notable emissions reductions calculated for cement and concrete.
Improved skills across FI	**Strong progress:** high level of beneficiary survey respondents and consultees reporting increased skills as a result of the Challenge.

Expected 2025 onwards	
Reduced carbon emissions	Emissions reductions depend on wider factors including market penetration and the carbon intensity of the grid. A third of beneficiary survey respondents had achieved or expected reductions in their own carbon emissions and 40% had achieved or expected reduced carbon emissions across their supply chain.
Improved international competitiveness Improved business performance/growth (e.g. jobs, turnover, exports, market share)	Improvements indicate actual/potential for improved competitiveness. **Encouraging signs that early progress has been made on business performance, with expectations of more to come:** • A third of beneficiary survey respondents achieved increased turnover, over half anticipate it. • A quarter of increased turnover achieved from exports. • A quarter experienced/two fifths expect improved productivity.

Source: SQW based on information from the Transforming Foundation Industries Challenge

New collaborations across FI and with the academic base

6.24 As described in the previous section, the Challenge delivered collaborations across the FI, with a third of CRD projects involving five or more of the FI sub-sectors. There were also twenty-eight research organisations taking part in 44 CRD projects, with 14 research organisations involved in more than one project. Most of the research organisations taking part in multiple projects were involved in two or three projects but one was involved in ten and another two organisations were involved with seven projects. Consultation feedback from businesses and academics was broadly positive about the extent of collaboration driven by the Challenge, with links across academia and industry in particular identified as being much stronger than before. It was also reported that the collaborations facilitated by the Challenge, involving multiple sectors, across supply chains, and bringing together competitors, was rarely seen elsewhere. In this respect, the Challenge is understood to have functioned like an 'honest broker', an independent party with the ability to bring other parties with a mix of both shared and competition interests together to work for a common purpose.

Reduced risk of innovation

6.25 One of the key impacts the Challenge was intended to influence was the risk of innovation, particularly the technical and economic risks of developing resource efficient technologies. Consultation evidence on this topic covered a number of issues. In general it was acknowledged that the Challenge had reduced the risk for those directly involved in the Challenge, with observations that there was no lack of demand for the Challenge's support in the form of CRD competitions and the IVP. The high levels of private sector investment were taken by a number of stakeholders to indicate that the Challenge's inputs and support had reduced risk for those private investors involved in or aware of the Challenge or its projects. Consultees also described the moderate impact of TFI in relation to the scale of the challenges faced by the FI.

"We live in a world where other countries can produce things cheaper and people are investing in certain technologies, like electrical infrastructure, more than us. So, yes, but more needs to be done."

Wider stakeholder

Increased private R&D investment and increased FDI in the UK

6.26 Investment is likely to be one of the earlier business outcomes from innovation so it is encouraging to see the value of private R&D investment on activity supported by the Challenge. UKRI's own data show matched private sector investment spend of £186m[52] against a co-investment target of £83m and £77m FDI against a target of £50m. Including £12.7m public sector matched funding and a further £149m investment in follow-on or related activities, the Challenge achieved a total of £347m investment.[53] The UKRI data also show an increase in tech-related investment has been achieved in 16% of projects, against target of 5%.

6.27 Evidence from the beneficiary survey indicates Challenge participants have increased private investment in their activities, with 43% reporting this outcome (15/35). The combined value of this additional investment for those who provided details (n=13) was £13.84m, including 10% FDI. A similar proportion of CRD participants consulted for the evaluation reported private equity investment (27%, 8/30).

Development and adoption of innovations/ technologies accelerated across the FI

6.28 There is good progress on supporting technological progression, as discussed earlier in this section (page 53) but progress on wider adoption is less well-evidenced.

6.29 Taken together, data from the Challenge and the beneficiary survey indicate grounds for cautious optimism on technology adoption, specifically that a proportion of technologies have potential for scale up and there is already industry interest in them. The Challenge's own data recorded 12 technologies adopted at scale, against a target of 30. Across those who have responded to this question (16), beneficiary respondents reported that 57 companies have tested/are testing the technologies developed through their projects, with one respondent reporting ten companies testing their technology. In addition, four companies have developed a commercially available new product/service that is in the market with another two thirds (25/40) respondents expecting their project to lead to a commercial product/service in the future. This might suggest that more time, support or investment is required for technologies to be taken up more widely.

6.30 Among consultees, there was acknowledgement of the complexity of translating technology development into adoption:

[52] Comprised of £99.4m investment from IVP investors, £61.6m of private investment for CRD projects, £20m for the glass facility, £3.8m for TransFIRe, £0.7m for Network+ (in-kind funding). This includes Form 1 (contractually agreed investment on a project) and Form 2 investment (additional non-contractual investment on a project) as defined by UKRI.
[53] The £347m includes Form 1, Form 2, Form 3 (investment on activity indirectly related to Challenge activity) and Form 4 (investment on follow-up to Challenge activity).

"There is a question of …adoption willingness and adoption ability. I think the ability to adopt new technologies is frustrated by regulation and planning. Taking one big area – hydrogen – take the issue of whether there is enough hydrogen to develop new plants?"

Wider stakeholder

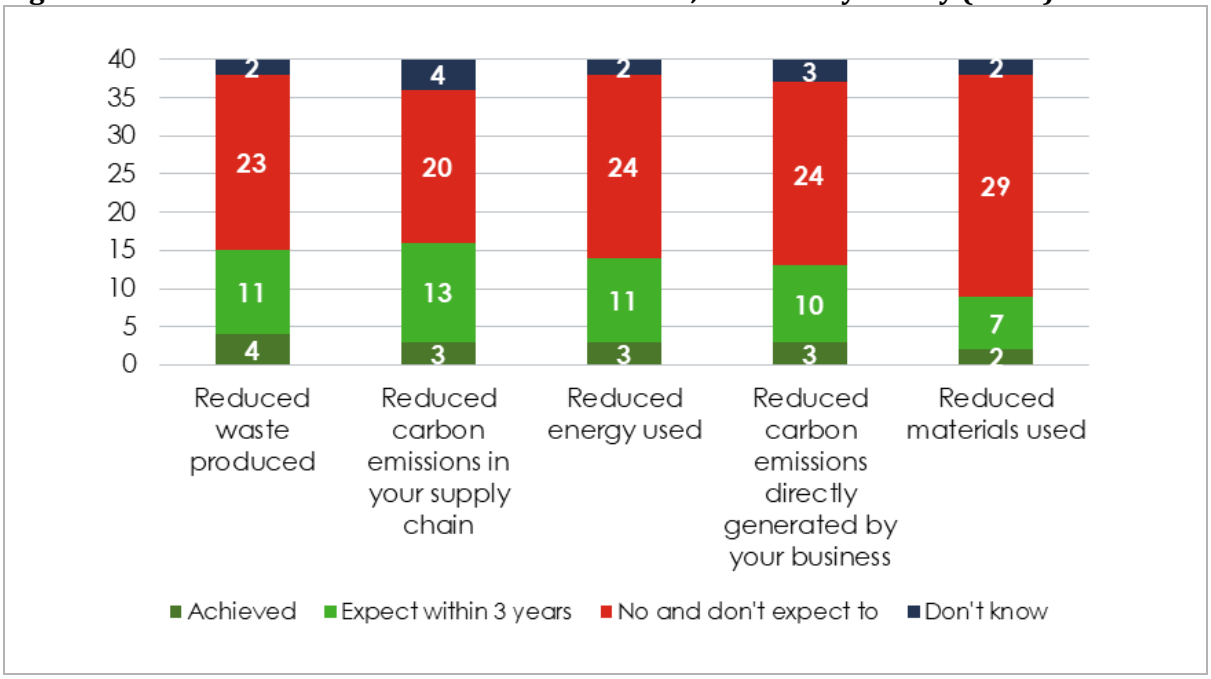
Skills

6.31 Survey and consultation evidence on the Challenge's impact on skills was strongly positive. Thirty-six of the forty beneficiary survey respondents reported staff having gained skills through participation in the Challenge: across these respondents, 143 people had been upskilled. Similarly, 27/30 CRD consultees reported experiencing enhanced innovation knowledge / skills as a result of the Challenge, 6/7 IVP business consultees reported the same and 9/12 academics consulted reported increased skills in relation to innovation and/or net zero.

Achievements on environmental impacts

6.32 The organisations participating in the Challenge have reported progress on key environmental metrics, with respondents to the beneficiary survey noting greatest achievement/confidence relating to reductions in waste (10% achieved, 28% expected) and supply chain carbon emissions (Figure 6-5) (note, the focus of the Challenge was on reducing materials and energy with carbon reductions expected as a longer-term impact). Respondents to the sector survey were also most likely to report actual or expected reduction in waste as the key environmental outcome (34% achieved, 20% expected).

Figure 6-5: Achievement on environmental metrics, beneficiary survey (n=40)



Source: SQW analysis of beneficiary survey

6.33 CRD participants consulted were also most likely to mention achieving/expecting reduced waste (22/30) and reduced energy usage (18/30), although a large proportion of the impacts were expected (14 and 13 respectively). Often this was because environmental impacts were anticipated on the basis of evidence at lab/pilot scale. For instance, one ceramics business believed they had achieved between 50% and 75% waste reduction in relation to the technology they were developing and a cement business estimated they had reduced the CO_2 per cubic meter of concrete by 40kg through their project.

6.34 All of the IVP participants consulted believed their technology would lead to reduced carbon emissions if it was widely adopted. Academics consulted were also optimistic about the environmental impacts of technologies developed if adoption followed:

"and impact in this form [environmental benefit] will continue to increase over time as a culmination of various things we did."

Academic participant

6.35 UKRI commissioned independent analysis of key projects by AtkinsRealis to quantify potential greenhouse gas emissions reductions. The report stated:

"the overall potential to reduce the combined cumulative carbon dioxide equivalent (CO_2e) emissions across all UK-based foundation industries was calculated to be up to 25,141 ktCO_2e for the 10 years between 2024 and 2035. Projected emissions changed year-on-year, based on a number of variables, including projected scale of uptake and decarbonisation of the UK National Grid."

AtkinsRealis, The GHG Impact of TFI Projects (December 2024)

6.36 Overall, there are some positive achievements on environmental impacts, as shown by the AtkinsRealis analysis and beneficiary survey findings in relation to reduced waste. However, AtkinsRealis found there were limited projects likely to lead to significant emissions reductions across ceramics, glass and paper, and major reduction depend on a range of factors including market penetration and the carbon intensity of the grid. In conjunction with the beneficiary survey findings that 60% or more of respondents did not anticipate key environmental benefits, it appears it will take time, favourable circumstances and additional support to improve the sustainability of the FI.

Achievements on business impacts

6.37 There is evidence of emerging turnover, employment and productivity impacts as a result of the Challenge, despite these not being anticipated until 2025 and beyond.

Turnover

6.38 The Challenge had a long-term aim to grow the FI but there was no target for increased turnover for participants as it was understood that mid-TRL innovation might take time to bear commercial fruit. Yet encouragingly, nearly a third of respondents to the beneficiary survey on

this metric (11/35) reported experiencing increased turnover, ranging from £30k to £2m (five of the 40 did not answer the question). In total, increases in turnover amounted to £3.28m to date. Of this, £0.9m (24%) was accounted for by exports, indicating that the Challenge has supported some companies to become more internationally competitive, one of the key aims of the Challenge. A greater number of respondents (57%, 20/35) anticipated increased turnover in the next three years/ amounting to a total expected increase of £23.6m. A similar proportion of sector survey respondents reported achieved and expected increased turnover (33% and 47% respectively, n=83).

Employment

6.39 As part of the Challenge's long-term aim to grow the FI, there were employment targets against which the programme collected some data.[54] Evidence from the beneficiary survey provides reassurance that the Challenge has made some difference to employment: a third of respondents (12/35) reported having already experienced increased employment for their business (five of the 40 did not self-identify as businesses). In total across these respondents there were c.50 gross new jobs created (FTEs). Across the more than half of respondents that expect there to be an increase in employment in the next three years (19/35), c.100 gross new jobs should be created.

Productivity

6.40 The beneficiary survey showed that around a third of respondents on this metric have already experienced productivity improvements (11/35) and another 40% (14/35) expect their project will lead to improved productivity in the next three years. This is similar to the proportion of respondents to the sector survey that reported having experienced productivity improvements (36%) and expect to experience productivity improvements (42%).

6.41 CRD participants consulted for the evaluation either reported achievement of improved business performance or expected these in future as a result of their project and half reported improved competitiveness (15/30). All six IVP participants consulted reported achieved/expected improved business performance. CRD consultees also described a range of unanticipated benefits such as an improved commercial strategy and better relationships with their customers.

6.42 Overall, while improved business performance was not anticipated to manifest within the Challenge lifespan, there are encouraging indications that, on some metrics, progress has already been made, with expectations of more to come.

Routes to outcomes and impacts

6.43 The Challenge was designed around five separate workstreams in which four models were tried and tested ways of working within UKRI: CRD competitions, the Investor Partnerships, the research hub called TransFIRe and Network+ (the latter was one part of Workstream 4). The

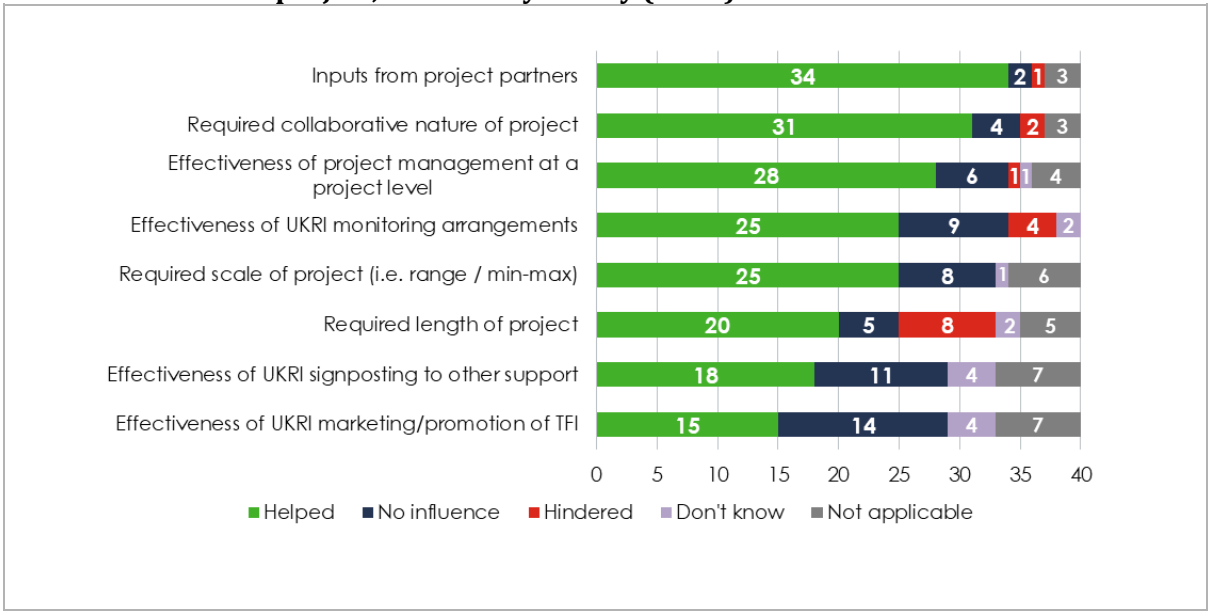
[54] The Challenge monitoring data reported 2,440 jobs retained against a target of 400 and 2,941 new jobs against a target of 5,000. Note, these are gross figures and it is not possible for SQW to verify them.

Challenge also included the development of a pilot-scale facility for the glass sector and a series of activities intended to develop a shared identity among the FI (these activities were the second part of Workstream 4). Evidence from the beneficiary survey, consultations with those involved in the Challenge, and case studies provide some insights into how those different models led to the outcomes and impacts reported above.

6.44 **The first step on the route to generating outcomes and impacts for the FI from innovation is providing grants and incentivising private investment** as the Challenge did in the CRD competitions and the Investor Partnerships. This addressed the most common barrier to R&D and/or innovation, as identified by ninety percent of respondents to the beneficiary survey, namely the financial risk associated with developing innovation / new technologies.

6.45 **The second key factor generating outcomes and impacts is collaboration**. Eighty-five percent of beneficiary survey respondents stated that inputs from project partners helped achieve outcomes and three quarters (31/40) respondents said the collaborative nature of the project helped achieve outcomes (Figure 6-6).

Figure 6-6: Aspects of TFI that have helped/hindered/had no influence in the realisation of benefits from the project, beneficiary survey (n=40)



Source: SQW analysis of beneficiary survey

6.46 The importance of funding to reduce risk and the central role of collaboration in producing outcomes are reiterated in feedback from consultations that emphasised the value FI-focused funding and opportunities for cross-industry and industry-academic collaboration. The specific focus on scale-up funding for technologies related to the sustainability of the FI by the Investor Partnerships was welcomed by both businesses and investors.

"The funding played a pivotal role in pushing them to consider their technology at a larger scale, aligning with the growing emphasis on impact and climate-focused investments."

Investor Partnerships business participant

Case Study – Intelligent Robotic Inspection for Foundation Industry Optimisation (IRIFIO)

i3D Robotics is a software engineering business that develops 3D imaging technology for heavy industry environments. Between August 2020 and October 2021, i3D delivered a Fast Start projected, IRIFIO, with two industry partners and a grant of £112.4k. This led to IRIFIO:D2, a Demonstrator project with over 10 partners and total grant of £2.1m. IRIFIO:D2 ran from October 2022 to March 2025.

Both IRIFIO and IRIFIO:D2 aimed to develop new smart vision technologies that could identify production defects in FI settings. The two rounds of funding enabled a successive programme of R&D, helping i3D progress technologies from proof of concept towards commercialisation.

Partner collaboration was critical to most stages of work. The delivery context was challenging, including Covid-19, energy crises, and inflationary pressures, but the following benefits are anticipated:

- *TRL progression of three technologies, almost to commercialisation, for application in the glass, ceramics and metals sectors that are 'new-to-firm' and 'new-to-market'.*
- *Follow-on investment and continued collaboration to achieve commercialisation for metals and ceramics technologies.*
- *Revenue generation for i3D once commercialisation is achieved.*
- *Improved efficiencies of FI industry processes, reduced waste and enhanced productivity when technologies are adopted e.g. through improved post-production brick sorting for ceramics manufacturers and improved identification of defects in the castings process for metals manufacturers.*

Wider benefits from the project include increasing participant understanding of the FI sectors, growth opportunities and constraints, new connections between partners and follow-on work.

Without TFI, only a small proportion of activity would have been delivered with far less collaborative input meaning benefits would have been achieved later, at a smaller scale and lower quality. TFI was critical in providing funding and facilitating collaboration.

6.47 The qualitative evidence also provides greater nuance on the routes to outcomes and impacts and insights in relation to the other workstreams (beneficiary survey respondents were CRD or IVP project participants).

6.48 **Funding and collaboration were likewise important to the glass facility**: without funding from TFI (and noting there was funding from other public sources), the facility could not have gone ahead. In this case, it was not about de-risking investment but making a significant capital construction project possible. Collaboration in the form of networks was also important to building engagement with parts of the glass sector and other FI.

6.49 **Collaboration was also at the core of how TransFIRE and Network+ were able to achieve outcomes**, according to consultees. The Challenge was seen to have been helpful in providing links to industry to underpin academic-industrial collaboration:

"I think we have achieved more than we set out to do as an academic led project, that is because we have had such strong industry engagement."

Academic consultee

6.50 Network+ was able to work effectively to generate outcomes because of the respective attributes of the individuals working together:

"The core members of the Network+, we come from such different technical backgrounds and have never worked before together (so) there was not a natural synergy for us to say, let's work together."

Academic consultee

6.51 For delivery team members and wider stakeholders with good knowledge of the Challenge, the level of outcomes and impacts achieved was driven by the combination of approaches, with a range of funding opportunities available and collaboration woven into all aspects of the programme. There are a few examples of this from participants, such as the CRD participant that also had involvement in the glass facility, but many of the participants did not seem to consciously experience being part of a programme. However, the positive evidence in relation to shared identity suggests that the volume of activity has strengthened the impression that the FI are a genuine sector. In addition, the Challenge responded flexibly to changing circumstances, for instance reallocating funding from IVP to CRD and the glass facility, to maximise delivery and increase the potential for achieving outcomes.

Progress against programme logic model

6.52 The Challenge performed well on achieving outcomes, particularly in terms of increasing a sense of shared identity among members of the FI, supporting participants to progress technologies, and generating good levels of private sector investment. The main gap is in the progress of the glass facility, which did not become operationally sustainable within the programme timeframe, due to delays in getting the furnace lit. But there are indications those outcomes are beginning to

translate into impacts such as the development and adoption of innovations, and even longer-term environmental impacts such as reduced waste and emissions, and business impacts such as increased turnover and productivity.

6.53 This assessment indicates that the Challenge had progressed most of the way through the logic model, underpinned by the key mechanisms described earlier in this section: providing grants and incentivising private investment to reduce the financial risk associated with developing innovation / new technologies; and driving collaboration that brought a range of expertise and experience to bear on shared challenges to find innovative solutions.

6.54 However, the context for the FI remains challenging, with significant work to be done to improve the sustainability of the FI. There is some uncertainty about the legacy of the Challenge after it formally closes and whether the early signs of impact will translate into sustained change in the sector.

7. Additionality and contribution

Summary

- **TFI had a medium-to-high level of activity and outcome additionality**, as reported by beneficiary survey respondents and Challenge participants interviewed for the evaluation. Ninety-five percent of beneficiary survey respondents reported full or partial outcome additionality.
- Across Challenge participants, academics reported the highest level of additionality, followed by the glass facility, CRD and IVP project participants, which might indicate that businesses have more options available to pursue different types of activity than academics.
- Relatedly, TFI has played a crucial role in realising benefits: more than three quarters of beneficiary survey respondents stated **TFI was the critical or an important contributing factor** in realising outcomes.
- Generally, feedback from both the survey and the consultees indicates that the decision to have collaboration in all aspects of the Challenge was sensible, with the expertise, experience and assets of partners cited as an important contributory factor in realising benefits. The value of contribution is evident across all the workstreams, from CRD projects to academic engagement and the glass facility.
- External factors such as market demand and policy were identified as both supporting and hindering the achievement of outcomes, depending on the specific circumstances.

Implications for the contribution story

- In terms of the ability of the Challenge to reach its longer-term impacts, the ongoing market and policy context will be crucial to whether organisations continue to pursue sustainable innovations.

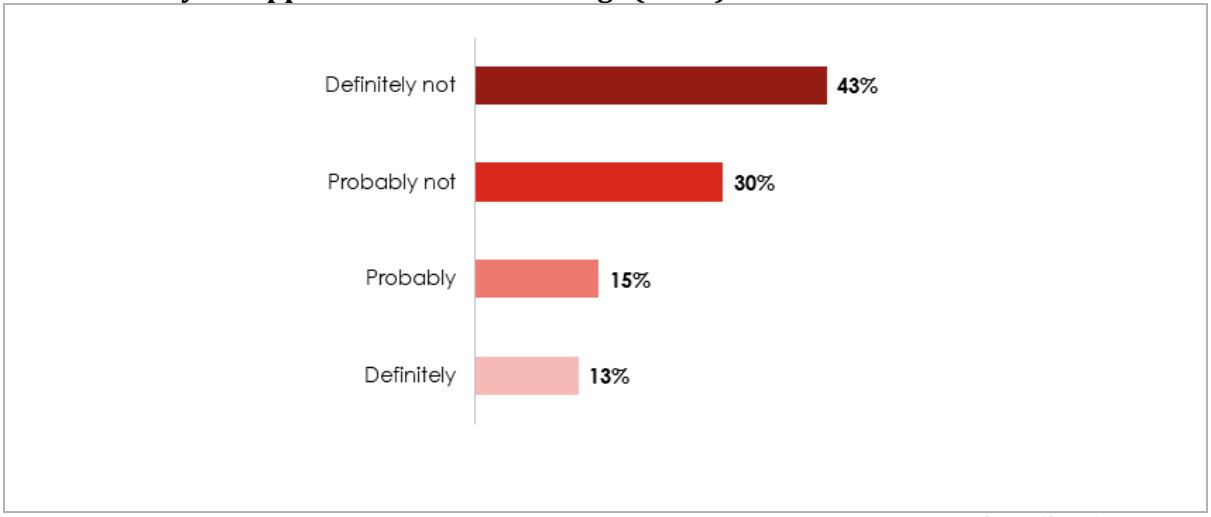
7.1 This section sets out extent of the additionality of the Challenge, that is the extent to which benefits are greater than those that would have occurred anyway in the absence of TFI, drawing on evidence from the beneficiary survey and qualitative evidence from consultees involved in the Challenge.

Additionality

Activity additionality

7.2 **The programme had a medium-to-high level of activity additionality:**[55] almost three quarters (73%, 29/40) of beneficiary survey respondents would have definitely not or probably not have not taken this or a similar project forward without TFI funding. Those reporting full additionality, that is those who would definitely not have taken the project forward without TFI funding, constituted 43% of respondents (17/40) (Figure 7-1). Ten of these respondents were small/micro businesses, potentially indicating that these businesses typically find it the hardest to find funding and other resources to undertake R&D.

Figure 7-1: Would you have taken forward this or a similar project if you had not been successful in your application for TFI funding? (n=40)

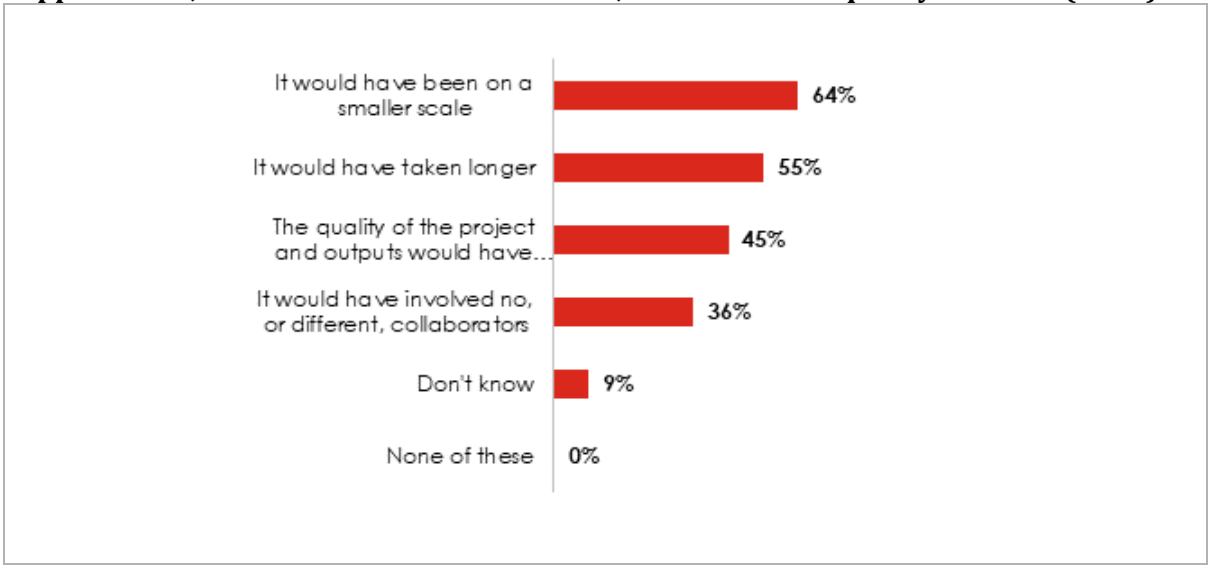


Source: SQW analysis of beneficiary survey

7.3 **Typically, TFI helped to increase the scale, speed and quality of the project as well as increase the extent of collaboration**: of those respondents who indicated that they probably or definitely would have taken forward their project or a similar project without TFI funding (n=11), 64% (7/11) said that it would have been on a smaller scale and 55% (6/11) reported it would have taken longer (Figure 7-2, note respondents could have indicated more than one type of additionality e.g. scale and speed).

[55] Additionality is self-reported i.e. the level of additionality is reported by the beneficiary themselves rather than being calculated against a comparator or using another method.

Figure 7-2: If the project would have gone ahead anyway, did the TFI funding allow it to happen faster, involve different collaborators, or increase the quality or scale? (n=11)



Source: SQW analysis of beneficiary survey. Question asked of those that who responded 'Probably' or 'definitely' to "Would you have taken forward this or a similar project if you had not been successful in your application for TFI funding?"

7.4 **Consultation evidence from beneficiaries corroborated the survey evidence** with half of CRD participants (15/30) reporting that they would not have been able to fund the projects without TFI. The other half may been able to source funding, for example internal resources or partner inputs, but at a lower scale leading to slower and smaller projects. Feedback from non-beneficiaries validates this finding: just over half (4/7) were able to deliver similar activities without TFI funding but to a smaller extent and lower quality. Nearly half of IVP participants (3/7) reported that their projects were unlikely to have gone ahead without TFI funding.

7.5 Academics involved in TFI and interviewed for the evaluation perceived a high level of additionality from the Challenge. Three quarters (9/12) reported full activity additionality, stating that without FI's intervention, the FI would not have collaborated in this manner, at this scale (FIs collaborating would not have happened). The remaining quarter of academics interviewed thought some engagement would have happened but more slowly and at a smaller scale.

7.6 Glass facility consultees reported a high level of additionality of the TFI funding (8/9 claimed full additionality, one reported partial additionality). The initial funding was described as being *"instrumental to enabling fit-out* [of the glass facility]*"*, and additional uplifts were reported to have helped cover unexpected costs.

7.7 The combined view of the delivery team and wider stakeholders was that TFI was highly additional, largely because there were no other viable sources of funding and no incentives for cross-sector collaboration. In particular, full additionality was seen to apply to the glass facility, the Sector Strategy activities and TransFIRe. Members of the delivery team conceded that the Challenge might only have achieved partial additionality in respect of the CRD and IVP projects, but importantly by speeding up activities, increasing the scale and quality, and encouraging a greater degree of collaboration.

Outcome additionality

7.8 **The Challenge had a high level of outcome additionality**,[56] with 95% of respondents who reported business benefits (employment, turnover, productivity, skills) identifying full or partial outcome additionality i.e. without TFI the benefits would have been achieved more slowly (6 respondents), at a smaller scale or to a lower quality (Table 7-1).

Table 7-1: What would have happened to the benefits reported above without TFI? (of those identifying key benefits, beneficiary survey, n=19)

Additionality		n	%
Would not have occurred at all	Full	11	58%
Would have occurred but at a slower rate	Partial*	6	32%
Would have occurred but at a lower scale		2	11%
Would have occurred but not the same quality		2	11%
All the benefits would have occurred	Deadweight	1	5%

*Source: SQW analysis of beneficiary survey. *Respondents could identify more than one type of partial additionality. In total, 7 respondents identified partial additionality.*

7.9 A similar distribution of opinion was found among CRD participants consulted for the evaluation:[57] about half reporting full outcome additionally and most of the others reporting partial additionality. There was very little deadweight reported. IVP participants reported even higher levels of outcome additionality, with 6 of 7 stating that they were unlikely to have achieved the same results within the same time without TFI funding.

7.10 Academic participants interviewed for the evaluation reported the highest degree of full outcome additionality (11/12 interviewees) as they believed there were no alternative programmes or funding sources available to facilitate the activities at the scale required to deliver the benefits experienced.

7.11 Glass facility interviewees were not able to comment on outcome additionality as the facility was not fully operational (the furnace was not lit before close of the Challenge) and thus outcomes were largely in the future. However, all consultees were confident that future benefits of the glass facility will be fully additional, as there is no other comparable facility or market offer available.

Displacement

7.12 **In supporting these projects, TFI has generally not displaced other research/innovation**: three quarters of beneficiary survey respondents (30/40) agreed that participating in TFI had not

[56] Self-report additionality.
[57] Note, the CRD consultees and the beneficiary survey drew on the same population (all organisations that were leads or partners in CRD projects) but the identity of the beneficiary survey respondents is not known to the evaluators. The CRD consultees may therefore overlap with the beneficiary survey respondents.

affected their ability to engage in other research/innovation. Of the other quarter of respondents, eight said participation affected their ability to undertake other research/innovation a little (8/40). Only two respondents reported that participation affected their ability to some extent or substantially: these were both micro/small businesses.

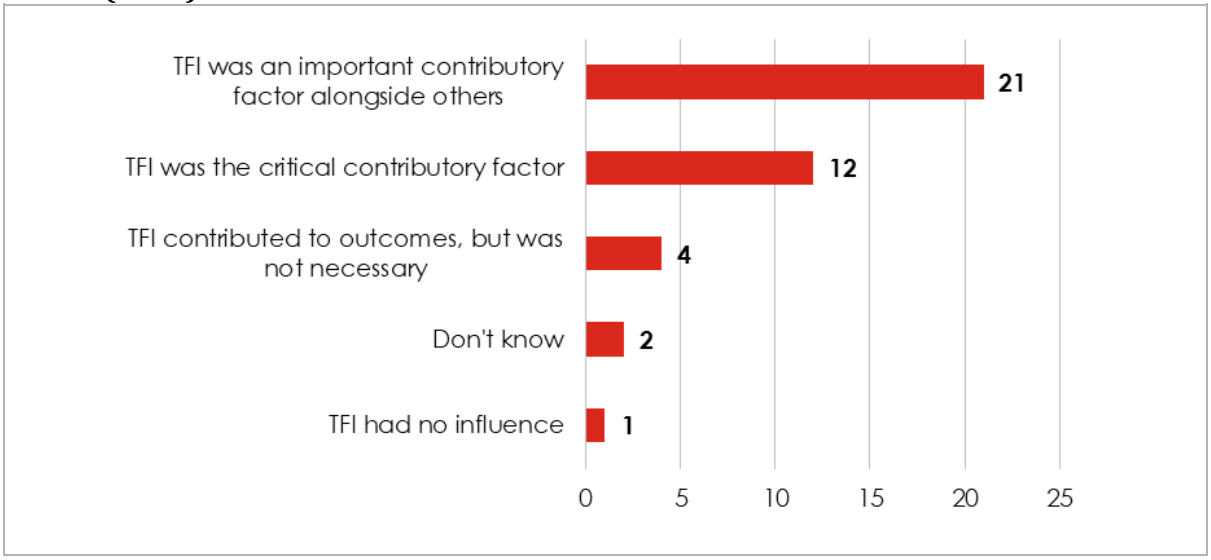
7.13 **TFI generally supported innovative projects that do not directly compete with other UK-based firms**. Forty percent of respondents to the beneficiary survey said that their technology or product did not, and will not, compete with other UK based firms. One third (13/40) stated that any such competition would be limited. Only four respondents reported that competition would be intense (three of these from the metals sub sector).

Contribution

Evidence from beneficiary survey

7.14 **TFI has played a crucial role in realising benefits for participants, alongside other factors**: more than three quarters of beneficiary survey respondents stated TFI was the critical or an important contributing factor in realising outcomes. (Figure 7-3).

Figure 7-3: Importance of TFI contribution to realising benefits compared to other factors (n=40)



Source: SQW analysis of beneficiary survey

Perspectives from participants

7.15 TFI was generally considered to be a critical or important contributory factor in the realisation of benefits by those involved in the Challenge and interviewed for the evaluation, across all stakeholder groups.

- TFI was considered a critical factor in the realisation of benefits from their project by nearly two-thirds of CRD participants interviewed for the evaluation (19/30), and another five CRD interviewees thought it was an important contributory factor.

- Among IVP participants interviewed, three of seven IVP interviewees described TFI as the critical factor in realising benefits and two described it as an important contributory factor.
- Among academics, half of interviewees labelled TFI as the critical factor and half as an important contributory factor in the realisation of benefits.
- Among the five glass facility interviewees, views were split three to two in favour of TFI being the critical factor instead of an important contributory factor.

Other contributing factors

7.16 **The top two internal aspects of the Challenge/**project that contributed to the realisation of benefits from projects (reported by 85% and 78% of beneficiary survey respondents and illustrated in the case study on Flue2Chem below) **were the inputs from project partners and the collaborative nature of the project** (discussed in the preceding section and shown in Figure 6-6). Other key internal factors included effectiveness of project management at a project level (70%), effectiveness of UKRI monitoring arrangements (63%) and the required scale of the project (63%). Over a third of respondents agreed that all factors listed had helped realise benefits. The factor identified most often as a hindrance to the realisation of outcomes was the required duration of the project (20%, 8/40), which chimes with qualitative feedback from participants about needing longer to achieve project objectives.

Case Study – Flue2Chem – Building a UK value chain in converting industrial waste gases into sustainable materials for consumer products

Flue2Chem sought to redesign and validate a UK value chain to convert carbon emissions into sustainable materials for consumer products. Flue2Chem was a large Demonstrator project, with a consortium of 17 partners, including BASF, a global chemicals producer.

BASF's role was to develop a catalyst to convert captured CO_2 to ethanol. Previous research had produced a catalyst that worked for carbon monoxide but not carbon dioxide and the cost was volatile due to the precious metal content of the process.

The project research used a digital modelling workflow that improved the efficiency of the catalyst selection process. BASF subsequently tested, confirmed and scaled the results up to produce ethanol from carbon dioxide with a catalyst with significantly reduced precious metal content. CO_2 from flue gas captured in British paper mills that were consortium partners was shipped to BASF and used to produce the ethanol.

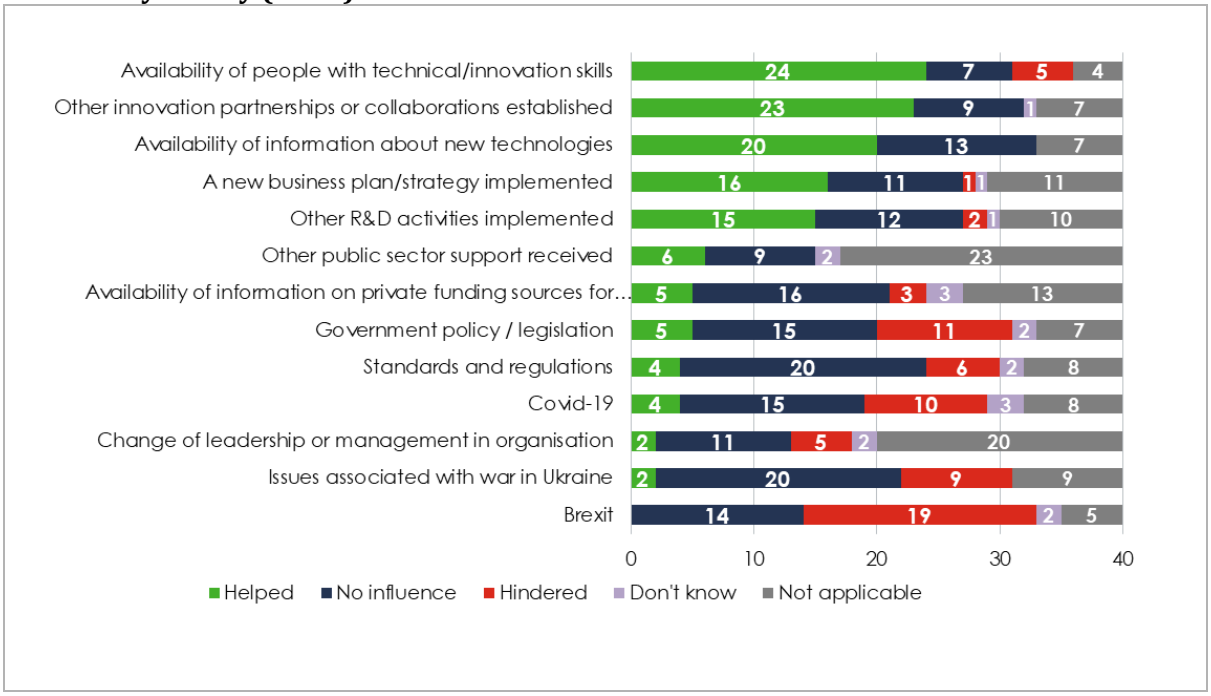
The Flue2Chem consortium is an example of how innovation can be driven by collaboration between partners bringing together a range of expertise in computational modelling, machine learning, and high-throughput experimentation. The consortium also included industrial partners from across the value chain from high carbon emitting industries (paper mills like Holmen and UPM) to consumer goods manufacturers (such as Unilever) that require chemical inputs.

TFI funding and the consortium developed as a response to the requirement to work in partnership were seen as instrumental to the success of the project. TFI required companies to work collaboratively thereby bringing together organisations for a common purpose where relationships did not previously exist.

7.17 The top two external aspects to the Challenge/project that contributed to the realisation of benefits from projects (as reported by beneficiary survey respondents) were the availability of people with technical/innovation skills (60%) and other innovation partnerships/collaborations (57.5%) (Figure 7-4). These correspond closely to the internal factors, underscoring the importance of collaboration as a way to bringing people and organisations with the requisite skills and expertise to deliver effective innovation. Availability of information about new technologies was helpful to half of beneficiary survey respondents, again reinforcing the importance of knowledge in the innovation process.

7.18 The factor that had the most negative influence on projects was the UK's exit from the EU, as reported by almost half of beneficiary survey respondents (19/40). Around a quarter found government policy / legislation, Covid-19, and issues related to the war in Ukraine to be a hindrance (11/40, 10/40 and 9/40 respectively).

Figure 7-4: Factors relating to the organisation and/or the wider context that have helped/hindered/have had no influence in the ability to realise benefits from the project, beneficiary survey (n=40)



Source: SQW analysis of beneficiary survey

7.19 Evidence from consultees involved in the Challenge largely cohered with evidence from the beneficiary survey although there was a wide range of factors listed as playing a role in achieving benefits across the different workstreams, both internal and external to the Challenge and the projects. Some of the most commonly cited internal factors in relation to CRD and IVP projects and academic engagement included partner knowledge, expertise and assets, previous R&D and a willingness to collaborate. These chimed with the factors identified by beneficiary survey respondents.

"TFI provided the money that enabled us to actually do the work but actually engaging with the companies that is really down to [us] and relies on our contacts and networks and people that we know. Lots of people know us."

TransFIRe academic participant

"Internally we have a large and diverse research and development arm within the company, and we try to do as much internal R&D as possible. Our size means we have lots of skills and lots of capacity to test various innovations."

CRD participant

"The primary accelerant was collaboration, with the expertise of the partner businesses meaning research was much faster and them emerging form the project with a ready-made supply chain."

CRD participant

7.20 Some of the external market factors most commonly cited by consultees were increasing demand for sustainable solutions among firms, legislation/regulation, and energy prices.

"Regulatory-wise, the drive for net zero and the way it has flowed down to organisations [has been an important factor]."

CRD participant

7.21 Other contributory factors to progress of the glass facility included: funding from other sources such as Liverpool City Region Combined Authority, St Helens Council, other Government departments and industry; funding from other TFI workstreams, primarily the CRD competitions, which helped develop a pipeline of R&D activities and opportunities for industry partnerships; and specific inputs such as favourable terms on the lease for the facility from St Helens Council and networking support from the TFI delivery team.

7.22 External factors were reported as both contributing to outcomes and hindering them, depending on the particular circumstances. For instance, the rise in energy costs put financial pressure on some companies that made protecting time and resource for CRD activity difficult yet at the same time it increased market demand for technologies and innovations that reduce energy use. In terms of the legacy of the Challenge, the ongoing market and policy context will be crucial to whether organisations continue to pursue sustainable innovations.

8. Value for money

Summary

- The Value for Money (VfM) analysis involved a balanced assessment of available evidence against the "3Es" (*economy, efficiency and effectiveness*) of the programme. In other words, we considered the programme's expected ability to deliver outputs, outcomes and impacts in line with the TFI logic model at a minimum cost to the public purse.
- VfM analysis was underpinned by the monitoring data, beneficiary survey and qualitative insights collected as part of both process and impact evaluations of TFI.
- There is positive evidence against all three of the Es.
  - **Economy:** in our view, the TFI programme had a modest budget relative to its scope. CRD funding was competitively allocated (c. 40% rejection rate) to a mix of SMEs and large corporations across FI sub-sectors. Supported projects exceeded targets on attracting additional investment (both UK based and FDI).
  - **Efficiency**: the programme met its delivery targets and demonstrated flexibility by reallocating the budget to overcome challenges created by the disruption from the Covid-19 pandemic.
  - **Effectiveness**: supported projects have low failure rate (90% are either live or completed), over half of surveyed beneficiaries reported at least 50% of expected short-/medium-term outcomes in line with the TFI logic model. Over two-thirds of surveyed beneficiaries expect to commercialise the technology they developed with TFI support.

Implications for the contribution story

- A definitive judgement on the effectiveness and overall VfM of the programme will only be possible at a later stage, since most of the benefits are still expected and only 10% of surveyed beneficiaries have already commercialised their technology. However, based on the evidence to date, TFI has been economical, efficient and effective in delivering the benefits in line with the programme logic model.

Approach: the "3 Es"

8.1 There are four important considerations for assessing the VfM of TFI. First and foremost, TFI is an innovation-focused programme. Many of its intended impacts that can be monetised have not had enough time to materialise to the full extent yet. For example, the jobs and Gross Value Added (GVA) created via successful adoption of technologies developed due to the investment from (or leveraged by) TFI.

8.2 Second, the programme is diverse in its objectives and ways of achieving them. The sector is broad, comprising six distinct industries (cement, ceramics, chemicals, glass, metals and paper). The overall aim is to grow the sector in a sustainable way and make FI internationally competitive. This overarching aim encompasses a multitude of enabling objectives, such as boosting interdisciplinary research, establishing new links between academia and industry, growing business investment in R&D. As a result, the pool of TFI beneficiaries is also diverse while being relatively small. The number of beneficiaries with particular characteristics (including their size, the TFI workstream they were supported through, their sector and the broad type of technologies they work on) is too small for creating valid comparison groups. Consequently, quasi-experimental analysis of programme outcomes is impractical.

8.3 Third, the programme is relatively small in scale compared to the size of FI sector, and other external factors (e.g. energy prices) have a particularly strong influence on foundation industries. Therefore, it is challenging to identify the role of the programme relative to those other factors.

8.4 Finally, the survey of beneficiaries has large margins of error. Despite strong response rates to the telephone survey, the modest overall number of beneficiaries meant that the survey sample was small. As a result, we had low levels of confidence in individual point estimates from the data (e.g. in the specific percentage of beneficiaries experiencing a particular positive effect or having a view on the level of additionality of benefits). Therefore, any attempt to extrapolate the outcomes reported in the beneficiary survey to the programme level would likely produce an inaccurate and potentially misleading estimate of the benefits.

8.5 In the light of these challenges, consistent with the evaluation framework for the TFI programme, our assessment of VfM did not involve calculating benefits-to-costs ratios (BCRs) or other similar metrics (e.g. costs per created job). Instead it was based on a balanced assessment of available evidence against the components of the "3Es" framework – the economy, efficiency and effectiveness of the intervention. Put another way, we critically analysed the evidence to determine the programme's expected ability to deliver outputs, outcomes and impacts in line with the TFI logic model at a minimum cost to the public purse.

8.6 The main sources of evidence for the VfM analysis included: monitoring data, beneficiary survey and qualitative feedback on delivery of the programme provided by stakeholders throughout the evaluation cycle (including during the fieldwork for the process evaluation report).

Economy

8.7 A programme achieves good economy if it can meet its objectives at the minimum public cost, without sacrificing quality and longevity of outcomes and impacts. To assess whether TFI minimised its costs, we:

- considered the overall budget of the programme against TFI's scope
- examined monitoring data on the number of applications for TFI funding, rejection rates and characteristics of beneficiaries
- analysed beneficiary survey evidence in relation to further funding attracted by supported projects (including FDI).

8.8 The evidence suggests that TFI has several characteristics of a programme with good economy:

- overall the budget for TFI was modest considering the scope, ambition and strategic importance of the programme
- the funding was competitively allocated to a mix of SMEs and large corporations
- supported activities leveraged additional finance (both foreign and UK private investment).

8.9 Table 8-1 summarises key statistics that highlight the scale and ambition of the programme relative to its funding.

Table 8-1: Programme scale and ambition

Programme characteristic	Headline figures/detail
Allocated funds	£66m initial budget
Five diverse workstreams with double focus	Funding successful R&D to advance the sector Fostering collaboration and sector identity to enable successful R&D
Additional funding attracted by the challenge (through CRD and IVP streams)	c. £165m of R&D UK investment (gross, target £83m) c. £77m of FDI (gross, target £50m)[58]

Source: SQW analysis of TFI monitoring data

8.10 Monitoring data suggest that there was a substantial level of competition for TFI's funding. For example, 114 applications were made for CR&D support across six main calls for proposals. Sixty-five of the projects were funded – this corresponds to a rejection rate of over 40%.[59] Over half of

[58] The FDI figures are based on monitoring data. Beneficiary survey evidence suggest more modest levels of FDI, that however could be down to the sampling/response.
[59] A further nine projects were funded through two additional calls added in response to the Covid-19 pandemic. However, since those were managed externally, SQW did not have access to the data on the number of applications.

the projects involved at least three organisations, and over half of beneficiaries were SMEs. Two-thirds of the projects involved partners from multiple FI sectors. These statistics suggest that TFI funds were appropriately distributed to leverage skills and expertise across the sectors and to combine agility and ambition of SMEs with the capacity and capabilities in disposal of large organisations.

8.11 In addition to the statistics on the level of additional R&D funding that was leveraged by the TFI Challenge (as shows in the table above), the beneficiary survey indicates that, for almost 40% of respondents, their project involved further investment into the research. These beneficiaries were a mix of large and small companies involved in different projects. This pattern is consistent with the additional resource being attracted by a range of TFI funded activities rather than concentrated in one successful outlier project or company.

8.12 One aspect of the programme that, if tweaked, could potentially result in an even better economy is the selection process and specifically the technological scope. The Challenge adopted a portfolio approach to selecting the projects to support across all its competitions. The priority given to projects spanning multiple sectors, however cross-sector collaborations were not mandatory in all competitions. Cost considerations were factored into the funding decisions, alongside application scores. All criteria were given equal weight in the selection process, rather than prioritising cost or any other aspect alone. This approach was appropriate. However, according to consultation evidence from the process evaluation, the number of applications could have been larger had the scope of funding calls been broader.[60] The increased competition from the broader scope could result in greater economy by providing additional incentive for the applicants to seek greater match funding and lower their ask for the Challenge's contribution towards the costs of their projects.

8.13 We acknowledge it is possible that in the case of TFI the excess number of applications for funding was not large enough to challenge the decision-making process. In other words, there may only have been a few similar projects competing on costs.

8.14 On the balance of evidence, we conclude that TFI did well to minimise the costs and appropriately distribute the funding. Under the assumption that most of currently expected outcomes will materialise, the programme has achieved good economy.

Efficiency

8.15 A programme is efficient if it delivers its target outputs at a minimum cost. Our assessment of TFI's efficiency was underpinned by our analysis of monitoring data and reflections of stakeholders provided during the process and impact evaluations.

8.16 TFI was efficient in achieving the planned levels of outputs despite major challenges associated with the Covid-19 pandemic. As discussed in Section 5, by October 2024, 94% of TFI funds were

[60] It is worth highlighting that the scope of the Challenge is signed off by HM Treasury and is beyond the control of the TFI delivery team.

used and the programme met delivery milestones across all workstreams. The funding was allocated across the workstreams largely according to the original plan, with some underspend across the CRD competitions, where reallocation of funds was limited by Innovate UK rules.

8.17 In our view, the programme demonstrated flexibility that allowed it to successfully navigate challenging macroeconomic conditions. The resources were appropriately reallocated towards two additional CRD calls that were created in response to the pandemic. Originally those calls were not supposed to be funded and managed by TFI, but applications fitted the programme remit. Additional spend was also necessary to ensure completion of the glass facility. Some uncertainty still remains around the date when the facility will be fully operational.

8.18 The process evaluation highlighted that the main challenge for the programme in reaching the output targets was the capacity of the delivery team. On the face of it, there is a trade-off between a programme's economy and efficiency: a larger team costs more but can meet the targets easier. This is where the quality element of the VfM assessment comes into play. Excessive workloads for the team can be detrimental to the quality and longevity of outcomes, e.g. if funding decisions are rushed in pursuit of targets.[61] It is important that all future, sector-focused, national interventions carefully consider the necessary resourcing for the delivery team to strike the balance.

Effectiveness

8.19 The effectiveness of a programme is its ability to generate intended outcomes and impacts from funded activities and outputs. We emphasise that our assessment of TFI's effectiveness is an early view of this aspect of VfM since the majority of the supported projects have not yet reached a point when their technology is commercially ready.

8.20 The main source of evidence for this strand of analysis was the beneficiary survey. A detailed discussion of reported outcomes and impacts can be found in Sections 6 and 7 of the report. Considering the timing of the evaluation, instead of focussing on specific benefits that are typically used to judge the VfM (e.g. additional increase in turnover) we took a cross-cutting view across a wide range of outcomes that have either been realised or are expected by the beneficiaries (Table 8-2).

Table 8-2: Realised and expected indicators of programme effectiveness

Outcome/impact	Realised/Expected
Attracting additional funding (UK based and FDI)	Realised
Progress of the technology through TRLs	Realised

[61] We note that there was no direct evidence that the quality of the TFI's decision process was substantially affected by the capacity. However, at this point in time it is also impossible to infer what would have been done differently and whether that would have had positive impacts had there been more capacity in the team.

Outcome/impact	Realised/Expected
Commercialisation (or testing) of technologies developed with TFI's support	Realised and/or expected
Employment growth	Realised and/or expected
Turnover growth	Realised and/or expected
Productivity growth	Realised and/or expected
Sustainability improvements (reduced use of materials, waste, energy, lower carbon emissions in the business and supply chain)	Realised and/or expected
Staff developing new skills as a result of TFI support	Realised
Increased willingness to invest in research and innovation	Realised
Increased shared identity of FI	Realised

Source: SQW analysis of beneficiary survey

8.21 We highlight the following key points in relation to outcomes and impacts that allow us to make a preliminary judgement about the effectiveness of TFI:

- the failure rate of supported projects is low – c. 90% of CRD projects are either live or completed[62]
- all but one of the surveyed projects reported at least one of the outcomes/impacts listed in Table 8-2
- approximately half of surveyed beneficiaries reported at least half of realised/expected positive outcomes from the support
- over half of surveyed beneficiaries progressed their technology through TRLs as a result of TFI support, and over two thirds of them expected to commercialise their technology.

8.22 Combined with the evidence of strong self-reported additionality and contribution of the programme (see Section 7), these figures suggest that TFI can be expected to effectively convert the funding into intended impacts.

[62] Sometimes failure can be seen as a form of success of R&D. Arguably, an innovation programme with very high success rate may be considered to be too conservative. However, in our view, this applies to the realisation of benefits rather than completion of projects. Not all technologies that are being developed through TFI will succeed in the market, and not all projects will generate all intended outcomes. However, bringing a project to completion rather than abandoning it allows the learning and is an indicator of effectiveness.

Overall assessment

8.23 The monitoring data, results of the beneficiary survey, qualitative insights collected as part of both process, and impact evaluations provide positive evidence against all three aspects of VfM – economy, efficiency and effectiveness.[63]

8.24 However, we note that there are uncertainties associated with the small beneficiary survey sample that underpinned our analysis as well as with the future success of TFI supported projects. Will the technologies that were advanced through TRLs due to TFI make similar progress through the market readiness stages? Considering that only 10% of surveyed beneficiaries have already commercialised their work, a further assessment at a later time will be needed to make a definitive judgement on the effectiveness and overall VfM of the programme. Further public support may be needed to allow some of the riskier or capital-intensive projects to reach the market and unlock the full benefits from TFI.

[63] Considering the beneficiary survey actively asked whether specific benefits have been realised or are expected (instead of asking an open question "What benefits have you experienced") the results were interpreted as evidence of expected outcomes or a lack of them, rather than a lack of evidence on potential outcomes. This slight but important distinction influenced our assessment of the evidence on likely effectiveness of TFI.

9. Scenario analysis

Summary

- Scenario analysis is a common business technique which aims to study probable multiple futures in a systematic way.
- In this study, scenario analysis was used to contextualise the evaluation findings, addressing the key question: **'In what ways (if any) has the TFI programme supported the resilience of the Foundation Industries in the UK?'**.
- **Overall, we observe that all of the following scenarios are supported and the programme is significantly robust to different futures:**
  - **Scenario 1: Constant flux** – there are no periods of stability because of constant external changes affecting the FI.
  - **Scenario 2: Constrained technology flow** – the flow of technology is not determined by innovation capacity but by external events.
  - **Scenario 3: Internally driven flourishing** – UK government research and industry have solved the problems of material circularity.
  - **Scenario 4: Externally fed flourishing** – UK government research and industry have solved the problems of Carbon Capture Use & Storage (CCU&S).

Implications for contribution analysis

- **The TFI Challenge supports the resilience of the FI**. Contributing factors to this include **(i) the range of projects supported** that tackle energy, material and other efficiencies without focussing on a single approach or a singular technology; and **(ii) the programme's increased capacity of the FI to work together**.

9.1 This section sets outs the findings from the scenario analysis to help contextualise the evaluation findings: to see whether the TFI Challenge is resilient to the scenarios developed at the baseline phase. The scenario analysis therefore addresses the key question: **'In what ways (if any) has the TFI programme supported the resilience of the Foundation Industries in the UK?'**[64]

[64] The scenario analysis examined the question 'what will drive the scale and nature of R&D and innovation investment in FI'.

9.2 The section focuses on how robust the programme is in helping the FI to survive potentially challenging futures. It presents the scenarios that were originally developed as part of the evaluation framework. These were informed by a review of the existing literature, stakeholder interviews, and CE's economic and environmental projections (see section 3). This included review of 47 reports;[65] 10 interviews across the sectors; and five workshops with stakeholders which involved developing seven scenarios. After discussions and with stakeholders, we rebuilt the scenarios and reduced the number of scenarios to four.

9.3 The Annex Report contains further detail on the original scenarios and scenario making process.

Scenarios

9.4 The four main scenarios and how well the TFI Challenge supports them are set out in Table 9-1.[66]

What is scenario analysis?

Imagining the future is an essential tool for all businesses to make flexible long term plans. For sectors like foundational industries, where investment decisions operate over long cycles and will have far-reaching consequences for the potential viability of further innovations, it can be crucial.

In scenario analysis, instead of trying to predict the future, the aim is to study probable and preferable multiple futures as systematically possible. Scenarios are imagined futures – they are not forecasts – that can help decision-makers understand what kind of futures are possible, how to prepare for them, what kind of ends are sought, and how to move towards the most desired ones. Scenarios are always internally consistent visions of the future with a plausible connection to the past. They are especially useful for planning purposes during periods of disruption or instability.

[65] Of the 47 reports, 10 were for general background, 11 cross sectoral and 26 on specific sectors.
[66] A 'business as usual or business as hoped for' scenario, essentially the future seen as most likely by many industry stakeholders, was also considered. In this scenario, demand continues to grow, technology breakthroughs are limited, and tougher environmental targets are set without new government policy or intervention. In sum, this represents a linear extrapolation of current circumstances.

Table 9-1: Summary of scenarios and how well the TFI Challenge supports them

Scenario	How well does the TFI Challenge support scenario?
Scenario 1: Constant flux • In this scenario there are no periods of stability because of constant external changes affecting the FI. • There are short periods of high demand, high throughput are rare and do not last. Downturns are often surprises (not cyclical). • Downturns are long and short, sharp and soft and come from multiple directions (geopolitics, economic downturns, weather, competitors). • It becomes increasingly difficult to confidently predict future demand and to match traditional investment cycles. • The following are expected: material flow disruptions, extreme demand disruption, dumping from international competitors, innovations flowing to China, and extreme challenges to investment cycles.	• Being robust to unexpected shifts in demand can be enabled by having a competitive industry that attracts orders during low demand periods, and by enabling an efficient industry that converts labour, energy and raw materials more efficiently than its competitors (and is hence more robust to any restrictions on those flows). • The programme tackles all issues of efficiency which is a strong positive The projects can be largely characterised as development of new technologies or tools that are incremental and in some cases disruptive. • A key indicator of robustness against constant flux is investment levels, The programme has done well in attracting private investment.
Scenario 2: Constrained technology flow • In this world the flow of technology is not determined by innovation capacity but by external events. The availability of money and customers waxes and wanes. Demand growth in Asia pulls money, factories and therefore investment Eastward. National governments either leave the FI to the market or set policies around a goal of material security. • In this scenario we expect FI R&D to shift to China, customers to leave the UK, and government policy to shift to material security.	• The programme offers ample and clear evidence that it has delivered a wide range of technologies that could work to transform the foundation industries. In this sense the programme has fulfilled its role completely.
Scenario 3: Internally driven flourishing • In this world, UK government research and industry have solved the problems of material circularity. The FI moves to a service model retaining ownership of molecules and bringing them back for reuse at end of life. Raw material imports continually decrease and new subsectors emerge.	• The programme has delivered a variety of projects and outputs that offer the potential to deliver carbon emissions reductions. This is a major achievement. • The programme has found great projects and offers a great selection among the various potential technologies.

Scenario	How well does the TFI Challenge support scenario?
• In this scenario we expect the supply of local recycled materials to eventually under-cut imported virgin materials, and the FI become the system that provides (re-cycles and renews) fundamental core molecules in service of the Nation.	• In a more limited way, the programme has also supported projects and created outputs that would increase material efficiency and circularity (these would naturally already act to reduce carbon emissions if implemented). • Overall, this scenario – which emphasises the FI trying to exercise more control over its future by directly finding new technologies and models – has been very well supported by the programme but less well supported with external/venture funding.
Scenario 4: Externally fed flourishing • In this world UK government research and industry have solved the problems of Carbon Capture Use & Storage (CCU&S), and Hydrogen production and distribution. Renewable electricity is cheaper than natural gas. The UK leads the world in low cost, low carbon foundation materials and easily finds export markets. • In this scenario we expect a vigorous FI enthusiastically adopting technologies driven by other sectors and/or government policy (such as CCU&S, hydrogen distribution), and FI becomes the system that takes low carbon energy and imported molecules to deliver materials in service of the Nation.	• This scenario is naturally passive for the technology developed within the programme, as it relies on technologies without (carbon capture etc) to solve many problems. In that way the programme is highly likely to succeed in its role, which is to work alongside these major technologies and further develop the sector. The programme has done this. • There is some argument that the programme has not focussed on developing innovations that would work deliberately alongside CCU&S and Hydrogen, so has not taken up the opportunity to make the sector ready for such a future event; but this is a limited criticism.

Source: University of Cambridge, Institute for Manufacturing; SQW

Overall resilience of the TFI sector and how the programme supports this

9.5 Taking into account the findings relating to the above scenarios, we highlight the following:

- **The programme does support all scenarios**. This is the best indicator that the programme supports the resilience of the foundation industries.
- **The range of projects supported** tackles issues of energy, material and other efficiencies without focussing on a single approach or a singular technology. This suggests a strong Darwinian logic of allowing different solutions to emerge.
- **The programme has <u>not</u> made the resilience of the sector worse.** While this may seem a rather negative comment it is of the utmost importance. The programme has not worked in a way that makes any scenario problematic.

9.6 We, therefore, conclude that all scenarios are supported and the programme is significantly robust to different futures.

9.7 **One of the most significant observations** is concerned with the mechanism of FI sector-wide innovation capacity building. The programme has undoubtedly **increased the capacity of the foundation industries to work together**, with multiple comments made about integrative conversations that would not have otherwise occurred.

9.8 While this is very positive and very significant as a new capacity, it should not be mistaken to be a substitute for trade association and government wide policy making, as it operates mainly across the innovators and therefore impacts only indirectly on CEOs and Ministers. **This is an exciting capacity that should be further exploited.**

10. Conclusions

10.1 This final section brings together the evaluation evidence and assesses the Challenge against the logic model, focusing on key benefits relating to innovation, collaboration, investment, and environment.

10.2 The Challenge has performed well in delivering activities and translating these into outputs in line with the programme logic model (Figure 4-1) in particular through CRD and IVP. Delivery has been broadly as planned with the FI sectors, organisations and collaborations supported in line with original expectations. Industry and academia have been willing to engage and collaborate in activities. There have been some delays in delivery (lighting the furnace in the glass facility so it is fully operational), underspend in IVP which was reallocated to CRD, and changes in TFI staff resourcing, which in the short-term slowed and changed the delivery of some activities. For example, Sector Strategy activities were not as quick to be mobilised as other workstreams.

10.3 The Challenge activities and outputs have been translated into outcomes in line with the programme logic model. The Challenge has performed well on achieving outcomes, particularly in terms of increasing a sense of shared identity among members of the FI, increased willingness to innovate, collaborate, and invest, technologies patented and progressed, and attracting interest from private sector investors. There are also indications that these outcomes are beginning to translate into impacts such as the formation of new collaborations across FI and with the academic base; reduced technical and economic risk of developing resource efficient technologies; and increased private R&D investment.

10.4 Other impacts such as increased FDI into the UK, the adoption of innovations/technologies, improved business performance and reduction in carbon emissions were expected to be achieved beyond 2025 but there are positive signs that these are likely to materialise in the future. Importantly, the observed outcomes (achieved to date and future) are additional, highlighting the value of the Challenge. While there are other factors contributing to outcomes, the Challenge is the critical or contributing factor, as indicated by beneficiaries and stakeholders.

10.5 Key to achieving benefits (to date and in the future) has been: public and private funding to de-risk projects, the collaborative nature of CRD projects, the flexibility shown by the Challenge in responding to circumstances, and the engagement with industry early on in the life of the Challenge and thereafter.

10.6 TFI has been economical, efficient and effective in delivering the benefits in line with the programme logic model. A definitive assessment on the effectiveness and overall value for money of the programme will only be possible at a later stage, since most of the benefits are still expected and only 10% of surveyed beneficiaries have already commercialised their technology.

10.7 The changes in the wider context that have occurred over the life of the programme affected the FI sectors. These included, for example, rising energy costs, disruption in supply chains, access to relevant skills, legacy of the Covid-19 pandemic, sector-specific shocks, and government policy e.g. imbalance between energy and resource reduction. These have been significant and have influenced the development of technologies and business benefits. Secondary data analysis on sector-level indicators for the period 2019-2024 provided a mixed picture on key economic and environmental data. This was against a general decline in output and employment in the manufacturing sector, driven by lower-cost competition from overseas and fragmentation of global supply chains. In this context, the evaluation findings can be considered particularly positive.

10.8 The scenario analysis described 'probable multiple futures' for the FI with their long investment cycles. This found that the TFI Challenge has supported the resilience of the FI in the UK. This is through: (i) supporting a range of projects that tackle energy, material and other efficiencies without focussing on a single approach or a singular technology; and (ii) the programme's increased capacity of the FI to work together.

Learning

10.9 We identify the following areas for learning going forward:

- Collaboration has been core to delivering programme outcomes. Part of the success of collaboration appears to be that it was welcomed across all sectors, businesses of all sizes, and across industry and academia. The premise that the FI has shared challenges that could best be met with shared solutions has been validated and future collaboration should therefore be supported while being mindful of the importance of demonstrating clear need and purpose. Future programmes could draw on the myriad examples of successful collaboration within TFI to promote cross-sector, and industrial-academic working.

- The Challenge was designed to spread risk via a series of CRD competitions and Investor Partnerships that invested less in a lot of different projects. Overall, this approach has paid off in that there have been lots of appropriate projects, a few potentially very impactful projects, and a few that did not make much progress at all. The key to raising the odds of having the strongest portfolio of projects is building on learning highlighted by consultees: having two stage application processes and starting early with feasibility projects.

- The large capital investment in the form of the glass facility was the biggest 'throw of the dice' by the Challenge. While it did not meet its key milestone of being fully operational, significant progress was made on construction, setting up management structures and a membership programme, and developing a pipeline of projects. Given the positive feedback from consultees and potential gains for the glass sector, there is a strong case for continuing support to get the facility fully up and running.

- It will be important to focus not just on product/service innovation, but also process innovation as a means of improving resource and energy efficiency. It can be argued that in particular cases process innovation may help to achieve benefits faster.
- Finally, maintaining support for innovation in the FI will be vital given the warm welcome for the Challenge, the benefits achieved to date, and the expectations for continued impact.

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