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Transforming Foundation Industries – Industrial Strategy Challenge Fund Evaluation

Evaluation Framework Report to UKRI

SQW

Contents

Contact:
Sarah Brown
Tel: 0161 475 2102
email: sbrown@sqw.co.uk

Approved by:
Osman Anwar
Director
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1. Introduction

1.1 The Transforming Foundation Industries (TFI) Industrial Strategy Challenge Fund (ISCF) programme includes six sectors within the foundation industries: ceramics, glass, cement, metals, paper and chemicals. The Challenge seeks to make the foundation industries (FI) internationally competitive and minimise their environmental impact through supporting collaboration, stimulating investment and de-risking innovation investment. The TFI programme is part of the Clean Growth Grand Challenge within the UK Government's Industrial Strategy. It has been allocated £66 million between 2019 and 2024 through the wider £4.7 billion ISCF. This is expected to translate into an additional investment of £83m from the private sector, potentially providing a total fund size of £149 million.

1.2 SQW, together with the Institute for Manufacturing (IfM), IFF Research and Cambridge Econometrics (CE), and a panel of sector experts, has been commissioned to evaluate the TFI ISCF. The evaluation will run from July 2020 to March 2024. The evaluation has four phases:

- Phase 1 – development of the evaluation framework, July 2020 to March 2021
- Phase 2 – baselining, November 2020 to May 2021
- Phase 3 – interim evaluation (process and progress), January 2022 to October 2022
- Phase 4 – final evaluation (impact), January 2023 to March 2024.

1.3 The purpose of evaluation, as noted in the Government's Magenta Book (2020),[1] is both to ensure accountability for public money by providing evidence on an intervention's impacts and to support learning. This evaluation framework has been developed with both these purposes in mind. It aims to rigorously assess the available evidence on what the Challenge has achieved and explore how change has been generated so this understanding can support the delivery of the programme itself and inform policy and initiatives beyond the lifetime of the Challenge.

1.4 The purpose of this report is fourfold:

- to confirm a shared understanding of the rationale for the programme, its key aims, and the expected routes to achieving those aims
- to set out the agreed evaluation research questions

[1] HM Treasury (2020) Magenta Book - Central Government guidance on evaluation. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/879438/HMT_Magenta_Book.pdf

- to present the overall approach to the evaluation, which has been developed to answer those research questions while taking account of the nature of the programme and the context in which it is operating
- to present a detailed methodology and data collection plan for the evaluation, outlining what evidence will be gathered, how, when and by whom (with the caveat that as the programme and context evolve the evaluation may need to respond and adapt).

1.5 The framework has been informed by: 22 consultations with key UKRI staff, and sector experts and stakeholders (listed in Annex A); a review of the TFI Challenge's programme documentation and data, plus wider literature on the FI (47 reports); initial analysis of secondary data and consideration of other secondary datasets; and development of plausible scenarios for the foundation industries. It builds on a positioning paper that was reviewed by the TFI team in December 2020 and has also been shaped by two workshops with the TFI team: the first on possible evaluation methods was held in December 2020; the second on the scenario analysis was held in January 2021.

1.6 A draft of the framework was subject to independent peer review at the end of February 2021. This version reflects amendments made in light of feedback from this review.

Report structure

1.7 The report is structured as follows:

- Section 2 provides a description of the Foundation Industries
- Section 3 presents the Logic Model and Theory of Change for the TFI programme
- Section 4 lists the evaluation research questions
- Section 5 lists the key indicators
- Section 6 sets out the overall evaluation approach
- Section 7 presents the proposed process evaluation methodology
- Section 8 presents the impact evaluation methodology
- Section 9 sets out the evaluation plan.

1.8 The following annexes are included as part of the report: consultees interviewed for the report; SIC codes for the Foundation Industries; TFI Challenge activities; a complete set of logic models and theory of change along with a list of evaluation indicators; data collection for monitoring of outputs; stakeholder mapping; a review of evaluation methods considered; detail on the scenario analysis strand.

2. Profile of the Foundation Industries

2.1 The term, foundation industries, is relatively new and, as such, there is no agreed definition of which businesses belong to the foundation industries. In essence, foundation industries are understood to refer to "manufacturers of core materials that supply other manufacturing and construction firms". For the purposes of the TFI ISCF, UKRI has included six sectors: ceramics, glass, cement, metals, paper and chemicals. These sectors are both assessed to be ready to engage with the programme[2] and likely to share common challenges amenable to common solutions, for example reducing energy use to support the move to net zero and adoption of newer technologies such as digital.

2.2 UKRI has a working definition of the foundation industries based on 2007 SIC codes for the six sectors (see Annex B:). The definition is focused on primary producers rather than firms adding value to basic products. The list of SIC codes will not be used to include or exclude firms from participation in the Challenge and will be updated by UKRI as necessary. Firms from different parts of the supply chain, as well as firms from entirely different sectors such as digital technologies, sensors and waste management, may be involved in the Challenge in terms of identifying challenges in the sectors and progressing efforts to overcome them.

Overview of the Foundation Industries

2.3 In 2018, the six sectors that comprise the foundation industries had a turnover of £53.5bn and generated GVA of £14.1bn[3]. Collectively, the FI employ 200,000 people directly in the UK through 4,747 enterprises[4]. Analysis shows the majority of direct jobs (86%) are located outside London and the South East, often in areas of economic deprivation (such as Grangemouth, Teesside, east coast of Yorkshire, Merseyside, the Midlands and South Wales).[5]

The sub-sectors at a glance

2.4 The following sections provide an overview of each of the six sub-sectors within FI. The statistics are drawn from analysis of ONS' Annual Business Survey and Business Register and Employment Survey by Cambridge Econometrics. The tables also include information from a draft report by the Enterprise Research Centre, *Innovation Readiness in UK Foundation Industries.*

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[2] For example, by cross-sector collaboration, engagement with the research base, and establishing a shared FI identity.
[3] BRES data, 2018
[4] ONS and BRES data, 2018
[5] Knowledge Transfer Network (2019) Transforming Foundation Industries: ISCF Challenge Workshop on Cross-sector Priorities.

Cement

Table 2-1: Overview of the cement sector

CEMENT

Key economic indicators (2018)	
GVA	£1.2 billion
Turnover	£4.3 billion
Employment	16,000
Number of enterprises	291

Subsectors

Consists of the manufacture of cement, lime and plaster, concrete and plaster products for construction purposes, ready-mix concrete, mortars and fibre cement.

Geography

Companies are predominantly owned by international businesses headquartered outside the UK.[6] Four main cement manufacturers operate in the UK; Tarmac Buxton Lime and Cement (Buxton), Hanson Cement (Birmingham), Cemex UK Cement (Liverpool) and Lafarge Cement (Rushcliffe). The sector is highly concentrated in the Midlands.[7]

Innovation

- Whilst the cement sector is not particularly R&D intensive, there has been some activity relating to product and process innovation.
- The energy-intensive nature of the sector is a key motivation for innovation, spurring process improvements across the industry to reduce its environmental impact.
- Another driver is the demand for high performance materials in the construction sector (e.g. new cement formulations) to meet building energy requirements.

Challenges

- Cost competition from abroad
- High building and maintenance costs associated with new cement plants mean that any capacity lost due to falling demand is unlikely to return
- Commercialisation of products relies on adoption by customers in the construction sector, and so any reluctance to use new materials will stifle innovation
- Unlike other manufacturing sectors, there are limited export sales.

Opportunities

- Planned expansion of infrastructure investment in the UK although is dependent on sustained demand from the construction market
- The requirement for non-fossil fuel energy sources will provide further opportunities to supply into the construction sector
- Using by-products from other industries can further reduce environmental impacts
- The high degree of foreign ownership within the sector provides an opportunity to access international best practice and technology.

Source: ONS Annual Business Survey 2018; ERC for UKRI (2020) Innovation Readiness in UK Foundation Industries

[6] WSP (2015) Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050.
[7] British Cement Association (2007a) The Cement Industry - Profile.

Ceramics

Table 2-2: Overview of the ceramics sector

CERAMICS

Key economic indicators (2018)	
GVA	£1.0 billion
Turnover	£2.1 billion
Employment	17,000
Number of enterprises	459

Subsectors

The ceramics sector consists of the manufacture of ceramic tiles and flags, bricks, tiles and construction products (in baked clay), ceramic household and ornamental items, sanitary fixtures, insulators and insulating fittings, technical ceramic products and other ceramic products.

Geography

Ceramics manufacturing is highly concentrated in the West Midlands, with the region employing more than double the number of people employed in all of the other regions in the sector combined. There is particularly high employment in Staffordshire, centralised in Stoke-on-Trent. There is also ceramics employment in East Midlands and the South West.

Innovation

- The ceramics sector has unrealised potential in its R&D and technical expertise.
- Early mover advantage over global competitors could be secured through working more closely with the UK's research base.

Challenges

- Cost competition from emerging economies
- High energy prices and reliance on raw materials from non-EU producers
- Lifestyle changes and substitution by other products
- Ability to attract and retain skilled workforce
- Access to funding
- Vulnerability to Brexit-related disruptions and uncertainties (with EU exports accounting for half of the sector's total).

Opportunities

- Recent expansion of global demand implies considerable growth potential for the sector.
- The UK's ability to exploit demand is dependent on a number of factors, including stable electricity prices, a sustained increase in construction output and favourable economic conditions.

Source: ONS Annual Business Survey 2018; ERC for UKRI (2020) Innovation Readiness in UK Foundation Industries

Chemicals

Table 2-3: Overview of the chemicals sector

CHEMICALS

Key economic indicators (2018)	
GVA	£5.7 billion
Turnover	£19.5 billion
Employment	48,000 people
Number of enterprises	1,167

Subsectors

The chemicals sector consists of the manufacture of industrial gases, dyes and pigments, other inorganic and organic basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic rubber in primary forms, pesticides and other agrochemical products, paints, vanishes, mastics and sealants, printing ink, soap and detergent, cleaning and polishing preparations, perfumes and toilet preparations, explosives, glues, essential oils and other chemical products.

Geography

Around half of UK production is concentrated in four main areas: the North West (21% of sector employment), Yorkshire and the Humber (12%), the North East (11%) and Scotland (5%). Chemical production in these areas is located in four main clusters – Hull, Teesside, Runcorn and Grangemouth.[8]

Innovation

- A strong UK R&D base entails a competitive advantage in innovative and high-value products.
- The sector spends over £5 billion each year on R&D.
- Innovative activity has contributed to productivity growth over the last 20 years.

Challenges

- Increasing global competition
- Fluctuating oil and commodity prices and high operating costs
- Lack of investment from global parent companies
- Shortage of workforce skills (including management & leadership)
- Brexit-related disruptions and uncertainties affecting both the regulatory framework and cross-border supply chain flows.

Opportunities

- The sector's importance to both the end consumer as well as a range of other manufacturing sectors provides a level of protection from demand fluctuations
- Digitalisation to reduce costs
- Development of shale gas to reduce the dependence on imports
- Increased demand for low-impact products and production processes.

Source: ONS Annual Business Survey 2018; ERC for UKRI (2020) Innovation Readiness in UK Foundation Industries

[8] House of Commons (2018) Chemicals Sector Report

Glass

Table 2-4: Overview of the glass sector

GLASS

Key economic indicators (2018)	
GVA	£1.1 billion
Turnover	£3.4 billion
Employment	21,000
Number of enterprises	513

Subsectors

The glass sector consists of the manufacture, shaping and processing of flat glass, along with the manufacture of hollow glass and glass fibres.

Geography

Businesses are clustered in the North West, East of England and the South East. Together, these regions account for a third of businesses in the sector.[9]

Innovation

- Innovation in the sector has focused on improvements in production processes aimed at raising productivity, reducing costs, and creating new innovative products.
- Innovation has been driven by:
  - regulation and new building requirements (e.g. specifications for the use of low-emissivity glazing) which has encouraged improvements in operational processes and continuous innovation in production techniques
  - pressure to reduce energy consumption, enabled by funding vehicles in place.

Challenges

- Barriers to accessing finance due to high upfront capital cost and long payback periods associated with investment in innovation
- The requirement for higher quality recycling infrastructure to improve the supply of high-quality cullet (broken/waste glass)
- High and fluctuating energy prices
- Brexit-related challenges: changes to the regulatory framework and trade policy
- Interconnectedness with the automotive sector, which is also vulnerable to Brexit-related challenges.

Opportunities

- Transition to net zero creates demand for high-performance products supplied to the construction sector. Commitments from the UK government on future house building could also be beneficial for the sector
- Covid-19 has presented some opportunities through the demand for protective screening in response to social distancing requirements.

Source: ONS Annual Business Survey 2018; ERC for UKRI (2020) Innovation Readiness in UK Foundation Industries

[9] ERC for UKRI (2020) Innovation Readiness in UK Foundation Industries

Metals

Table 2-5: Overview of the metals sector

METALS

Key economic indicators (2018)	
GVA	£1.6 billion
Turnover	£12.1 billion
Employment	36,000
Number of enterprises	900

Subsectors

The metals sector consists of the manufacture of basic iron and steel and of ferro-alloys, tubes, pipes, hollow profiles and related fittings, of steel; the cold drawing of bars, cold rolling of narrow strip, cold forming or folding and cold drawing of wire; the production of precious metals, aluminium, lead, zinc and tin, copper and other non-ferrous metals; processing of nuclear fuel; casting of iron, steel, light metals and other non-ferrous metals.

Geography

The UK metals sector is concentrated in the Midlands, North of England and Wales. Scotland and Northern Ireland also have production capacity, despite this declining in recent years.[10]

Innovation

Technological advancements in the sector have started to transform metal production from a labour-intensive process towards further automation, higher efficiency and sustainability.

Challenges

- The metals sector in the UK has declined between 2008 and 2018
- Global competition has resulted in closure of some large UK plants and threats to others
- Loss of competitiveness due to comparatively higher energy costs in the UK
- Brexit-related uncertainty has led to many existing foreign customers choosing to source products from elsewhere.

Opportunities

- Plans for upgrading the UK's energy and transport infrastructure are expected to result in additional demand for metals
- Additional demand from the development of new generations of vehicles, aircraft and other products
- Metals are reusable and recyclable, which makes them more attractive in a circular economy than single-use materials.

Source: ONS Annual Business Survey 2018; ERC for UKRI (2020) Innovation Readiness in UK Foundation Industries

[10] ERC for UKRI (2020) Innovation Readiness in UK Foundation Industries.

Paper and pulp

Table 2-6: Overview of the paper and pulp sector

PAPER

Key economic indicators (2018)	
GVA	£3.4 billion
Turnover	£12.2 billion
Employment	62,000
Number of enterprises	1,417

Subsectors

The paper sector consists of the manufacture of pulp, paper and paperboard, corrugated paper and paperboard, sacks and bags, other paper and paperboard containers, household and sanitary goods and of toilet requisites, paper stationery, wallpaper and other articles of paper and paperboard.

Geography

The paper-based industries are widely spread throughout the UK, with concentrations in the North West and South East of England, Wales and Scotland.[11]

Innovation

- The sector continues to improve existing products. However, the level of R&D investment (£0.1bn in 2019) is low compared to other FI, especially given the sector's scale
- Significant investment is required for the sector to remain innovative and competitive
- Whilst the sector is energy-intensive, it contributes to resource efficiency and carbon emission reduction through the recycling of paper.

Challenges

- Increasing global competition, including from other substitute products e.g. plastics
- Barriers to accessing finance due to the capital- and energy-intensiveness of the sector, coupled with long investment cycles of up to 30 years
- High energy prices.

Opportunities

- The sector continues to grow, driven primarily by changing consumption patterns.
- Growing trend towards the replacement of non-renewable resources with renewable
- Re-shoring the reprocessing of some currently exported recycled paper can help increase the proportion of forest fibre produced in the UK
- Ongoing collaboration with the UK Government to develop a 2050 roadmap which would enable the sector to meet the goal of 80% emissions reduction whilst maintaining its energy performance.

Source: ONS Annual Business Survey 2018; ERC for UKRI (2020) Innovation Readiness in UK Foundation Industries

[11] BEIS (2017) Pulp and Paper Sector: Industrial Decarbonisation and Energy Efficiency Roadmap Action Plan.

Implications for the evaluation

2.5 There are clearly common challenges among the six FI sub-sectors, which support the rationale for a single ISCF Challenge for the FI (explored further in the following section). Equally there are important variations between the sectors in terms of current levels of innovation, opportunities and challenges. The political and economic context is likely to change during the course of the evaluation in ways that affect the sectors differently and to different degrees. The evaluation will need to take account of differences between the sectors in assessing change over time, the different routes by which is change is generated, and the specific role of the programme in affecting change in each sector.

3. Logic model and theory of change

3.1 It is considered good practice and recommended in government guidance on policy evaluation,[12] to develop a logic model and theory of change that explicitly articulates the context and rationale for a policy or programme, and describes the relationship between the inputs, activities, outputs, outcomes and impacts. This instructive tool helps to structure an evaluation and inform the collection of evidence that would test whether the underlying logic and theory has happened in practice. Using the tool helps evaluators to test the extent to which, and how, the outputs, outcomes and impacts have been achieved and the causal links between these and the activities (i.e. the theory of change). In short, the approach provides the basis for developing a coherent monitoring and evaluation framework in two ways:

- informing the identification of indicators for monitoring and assessing performance
- outlining the main features of an intervention and in doing so framing the key research questions for the evaluation.

3.2 This section sets out a refined logic model and theory of change for the TFI programme. This has been developed by drawing on the original 'Benefits Map'[13] that was set out by UKRI and is also informed by our scoping discussions and document review.[14] Specifically, it sets out the *Strategy* (context and rationale), *Delivery* (inputs and activities) and *Benefits* (outputs, outcomes and impacts) of the programme. A more detailed logic model with supporting theories of change for each of the five programme workstreams can be found in Annex D.

Strategic context and rationale

3.3 The competitiveness of the UK's foundation industries is important both economically and environmentally. The sectors are vital for the manufacturing and construction sectors, and are critical to the functioning of many other parts of the economy. If the foundation industries become less competitive, this presents risks to the rest of the supply chain. Over-reliance on imports in these sectors is also a concern, given the potential consequences for the supply chain in the event of international disruption. Competitive, resilient FI are therefore a strategic security issue. The six sectors are also heavy users of energy and producers of greenhouse gases: together they generate 10% of all UK's CO2 emissions while contributing 3% of total GVA.

3.4 Given FI are capital intensive and associated with high consumption of raw materials and energy in production, the Government's commitment to move to a 'net zero' economy means

[12] HM Treasury (2020) *Magenta Book: Central Government guidance on evaluation*.
[13] UKRI (20 April 2020) *Benefit Map – Transforming Foundation Industries Challenge – Wave 3 ISCF. Issue: 0.9 DRAFT.*
[14] UKRI, (30 April 2019) *ISCF Transforming Foundation Industries Business Case.*

that the UK's FI must accelerate the pace at which they reduce their emissions. It also underlines the importance of cost-effective policy interventions to maximise opportunities for economic growth as the UK transitions to a green economy, whilst not putting businesses at a competitive disadvantage. This is pertinent in the context of cost competition from abroad due to larger scale-lower cost production and greater support for innovation for FI in other countries, as well as lack of skills and experience associated with change, innovation and newer technologies such as digitalisation within FI. There is an opportunity for a disparate group of six sectors to work collaboratively to address the following common challenges to remain internationally competitive and become more 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 (note that these sector characteristics will also have implications for what can be achieved and measured within the evaluation timeframe, which is discussed further below and in Sections 4 and 5). The technologies and systems currently in place stifle innovation (e.g. traditional technologies and systems are preferred, preventing the benefits of data-driven processes) while 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:*** private investors lack understanding of innovation and technologies developed and used by firms within FI, limiting access to private finance. 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.
- ***Negative externalities:*** FI are the largest industrial polluters, accounting for around 10% of the UK's total carbon emissions. This wider environmental cost may not be fully taken into account by producers, potentially limiting the incentive to modify/ invest in their processes.
- ***Positive externalities (spillover benefits):*** technology advancements within (and across) FI and other sectors (e.g. manufacturing, construction) lead to positive externalities through 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.

3.5 Given the above, 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. In this way, the TFI ISCF aligns with the overall ISCF objectives, particularly:

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

- Increased business-academic engagement on innovation activities relating to Challenge areas
- Increased overseas investment in R&D in the UK.

3.6 There is also partial alignment with the objective: increased collaboration between younger, smaller companies and larger, more established companies up the value chain. The TFI ISCF is focused on collaboration across sectors and with academics rather than companies of differing size and/or age.

3.7 The TFI ISCF investment is, in turn, expected to increase international competitiveness and contributes to the Government's net zero target. The focus of the TFI ISCF will be on 'resource and energy efficiency'.

3.8 As an additional reason for intervention, the majority of employment in FI is outside the South East and there are some high concentrations of employment in areas of relative deprivation (see Section 2). Raising levels of innovation, productivity and employment opportunities within these sectors should therefore contribute to the government's levelling up agenda.

Objectives

3.9 According to the Business Case, the overarching aim of the programme is as follows:[15]

By 2024, transform the UK's Foundation Industries so that they are internationally competitive in manufacturing products vital for the economy in an environmentally sustainable way.

3.10 This is underpinned by five key programme objectives, relating to **Error! Reference source not found.**: 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.

3.11 The scoping discussions indicated that while all the objectives were considered important, there was some uncertainty over which ones should be prioritised (and how) to ensure programme outcomes and impacts are maximised, and address the original rationale for the intervention (i.e. the common challenges described above).

3.12 The objectives are likely to be addressed over different timescales during and beyond the evaluation period (2020-24). This reflects the nature of the long investment cycles as associated with FI, as indicated above, and the length of time it takes for innovations to occur.

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

3.13 The five high-level objectives, and aligned to these, the specific measurable objectives are presented in Annex D. The objectives are also summarised below:

1. Accelerate innovation and new collaborations across the sectors via delivery of Pilot Scale facilities and CR&D
2. Increase multi/inter-disciplinary research and innovation across the sectors through supporting development of the foundation industries as a sector
3. Develop closer academic and industry links through programmes dedicated to technology transfer
4. Accelerate growth of new technology and fast-growing businesses across the value chain through co-investment with Private Equity
5. Increase FDI in the UK and business investment in R&D via CR&D and pilot scale facilities

Inputs and activities

3.14 The key programme inputs include ISCF grant funding (£66m) and industry matched funding (£83m). There is further in-kind time, resource, expertise/knowledge from the ISCF team, industry and academia. The standard core programme delivery team is supported by wider UKRI support functions, as required. 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 will be reviewed regularly.

3.15 The programme is organised into five workstreams of activities as shown in Table 3-1. These aim to accelerate growth in the foundation industries (workstream 1 and 2), and transfer knowledge and scale new technologies (workstreams 3-5).

Table 3-1: TFI programme – Activities

#	Workstream and ISCF grant funding	Key activities
1	Establishment of the foundation industries pilot scale facility (£15m)	• Construction of a pilot facility (incl. equipment) for the glass sector in St. Helens
2	CR&D and phased demonstrators to support industry (£31m)	• Series of industry led CR&D competitions
3	New approaches to sustainable foundation industries – connecting universities and firms (£5m)	• Competition organised to facilitate knowledge transfer from academics to companies, with companies providing matched funding for projects

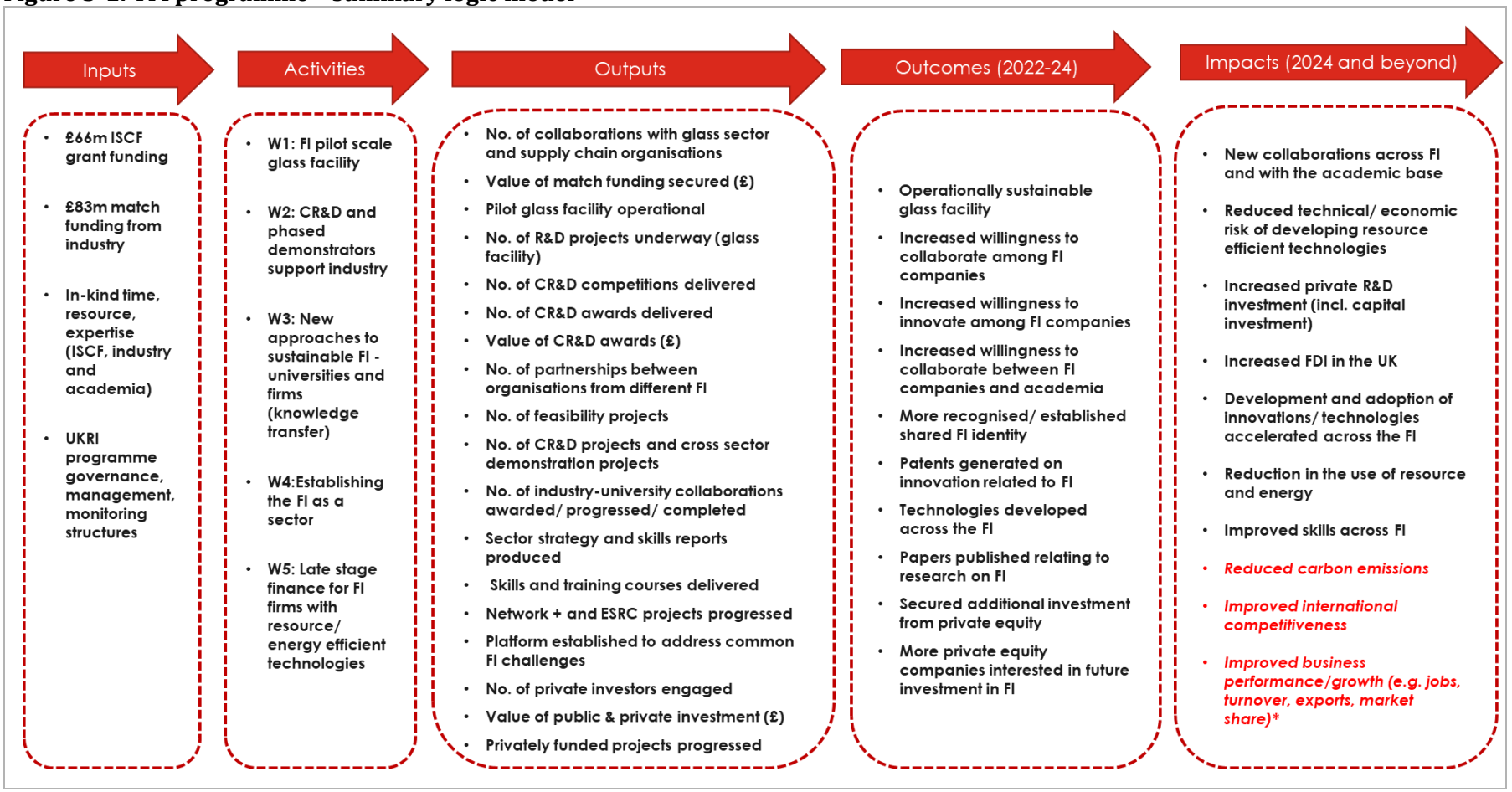
#	Workstream and ISCF grant funding	Key activities
4	Establishing the foundation industries as a sector (£5m)	• Sector strategy • Part of Network+ • coordination and development of a network across the foundation industries • competition for small projects • research papers produced • ESRC activity • Skills (TFI sector skills report; training and skills development)
5	Investor Partnership (£10m)	• Selection of investors • Funding competition for companies
	Challenge level	• *Central marketing activity; monitoring data collection; and governance activities etc.*

Source: UKRI

Summary logic model for the TFI programme

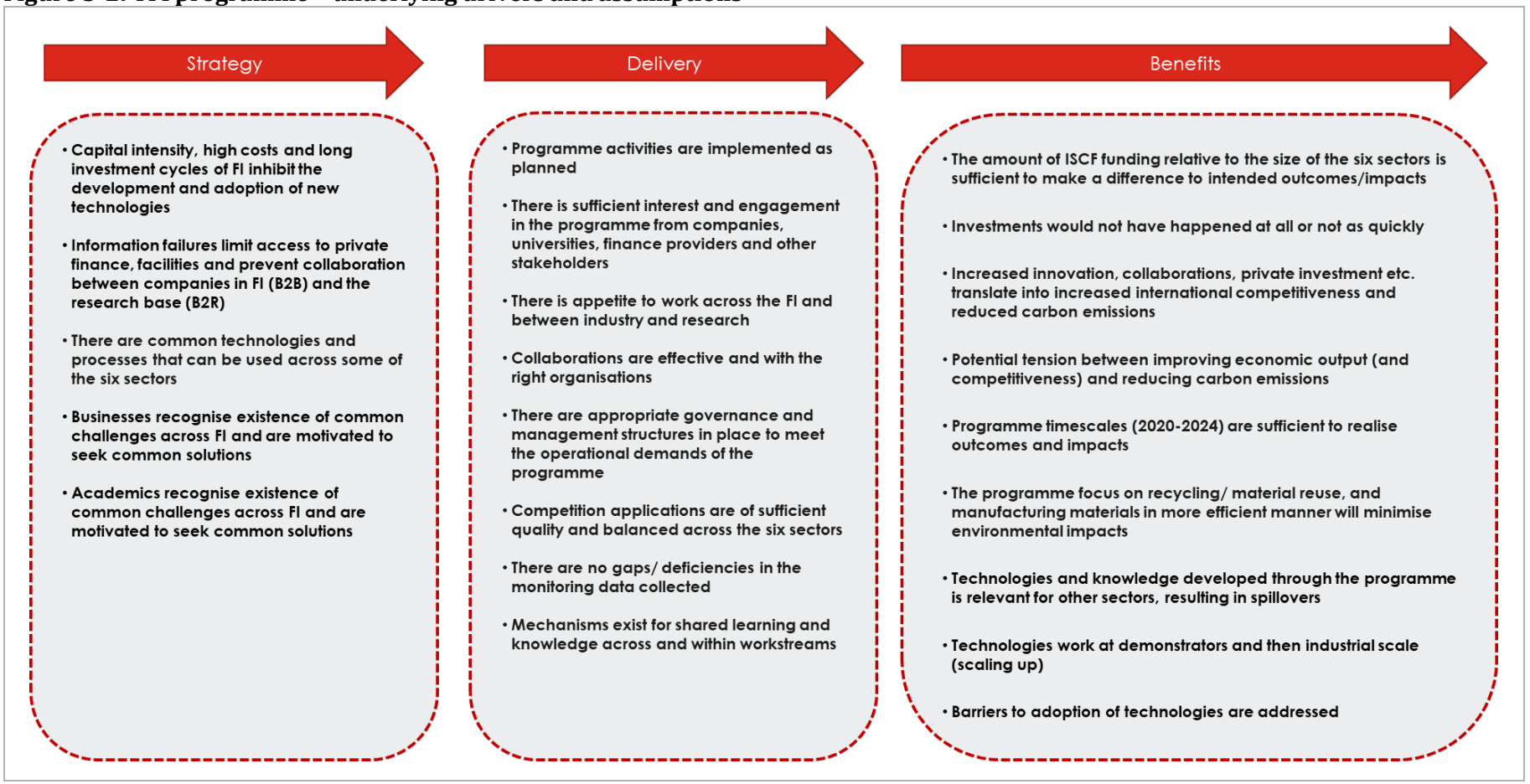
3.16 A detailed logic model covering the TFI programme's activities, outputs and outcomes and impacts are detailed in Annex D. A summary logic model and the underlying drivers and assumptions are presented in Figure 3-1: and **Error! Reference source not found.**.

Figure 3-1: TFI programme – summary logic model



*Source: SQW; UKRI; Impacts highlighted in red italics more likely to be measurable post-evaluation (beyond 2024); * These impacts in red italics can be covered at the end of the evaluation and after*

Figure 3-2: TFI programme – underlying drivers and assumptions



Source: SQW; UKRI:

Theory of Change

3.17 The ToC outlines the underlying drivers and assumptions identified in **Error! Reference source not found.** and the alternative/complementary explanations for the programme (summarised below) will need to be tested through evaluation in order to understand whether and how desired effects have borne out in practice. As such, they help to inform the evaluation research questions, set out in section 5. The ToC for the TFI programme is summarised as follows.

3.18 The capital intensity, high costs and long investment cycles of FI inhibit the development and adoption of new technologies. There are also information failures, whereby firms have limited access to private finance, facilities, and are prevented from forming new and effective collaborations between companies in FI (B2B) and the research base (B2R). Alongside this is the assumption that businesses and academics recognise the existence of common challenges across FI and are genuinely motivated to seek common solutions (i.e. bottom-up rather than top-down approach from policymakers).

3.19 The programme's five workstreams of activities lead to short-term 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, CR&D projects awarded and progressed, and investment in clean tech. The outputs are achieved through activities being implemented as planned by the TFI delivery team with in-kind support (time, resource, expertise) from the ISCF team, industry and academia. There is sufficient interest and engagement in the programme from companies, universities, finance providers and other stakeholders. Relatedly, there is appetite to work across the FI and between industry and research. In addition, applications are of sufficient quality and balanced across the six FI sectors. To maximise the effectiveness of delivery, mechanisms exist for shared learning and knowledge across and within workstreams.

3.20 The outputs for each of the workstreams translate into the medium-long term outcomes as indicated in Figure 3-1: . These are brought about through several key mechanisms:

- there is continuation of the allocated programme funding and that 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[16] change attitudes towards innovation, and contribute to better diffusion and adoption.

3.21 In turn, the above mechanisms contribute to final impacts such as reduced risk, increased innovation, private investment (one of the key overall ISCF objectives is "increased overseas investment in R&D in the UK"), international competitiveness, improved business performance and reduced carbon emissions.

3.22 In realising benefits there may well be a potential tension between improving economic output (and competitiveness) and reducing carbon emissions – the two may not necessarily be aligned. It is also likely that some projects/companies will succeed, and others will fail. Overriding all of the above, is the assumption that the programme timescales (2020-2024) will be long enough to realise outcomes and impacts, especially in a changing context.

3.23 The alternative and/or complementary explanations that are likely to influence benefits described in the logic model are summarised as follows:

- wider government policy influences innovation and sustainability, for example incentives to reduce energy use.
- other relevant programmes accessed by the TFI programme beneficiaries including from UKRI, Innovate UK, BEIS, 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.
- wider economic, social and political conditions affect the FI sectors, notably COVID-19 and Brexit, are likely to be significant, and influence the development of technologies and business benefits, and make 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
- there are inherent business behaviour/actions that may influence benefits, including:
  - internal business factors influence benefits, such as development and adoption of new technologies

[16] For example, there are potential linkages between workstreams 2 and 3 in working on collaborative projects/ sustainability challenges.

- technologies and knowledge generated is not the result of TFI programme funding per se, but from other/previous R&D
- collaborations are not new but from existing supply chains and networks
- companies would collectively invest in mutually beneficial facilities, e.g. in partnership with universities.

3.24 These alternative/complementary explanations will need to be tested in the evaluation to ensure attribution (or contribution) of the programme to the outcomes and impacts identified in the logic model. They will also help to understand where the Challenge is dependent on other factors, which is important for learning about the contexts in which effects have been brought about and to inform wider policy.

Example theory of change – CR&D competitions

The foundation industries' attitudes and barriers to investment in R&D, long-time horizons for investment and issues of commercial viability contribute to under-investment in FI and hinder the sector from becoming more environmentally sustainable. A series of industry led CR&D demonstrator competitions are delivered to encourage collaboration within and between companies in FI to address common FI challenges and opportunities. Companies come together that would not have done otherwise and put forward successful (and unsuccessful) projects for CR&D awards. This assumes demand is of sufficient quality and the right projects are funded (i.e. meet the Challenge aims of improving competitiveness and sustainability). It also assumes a 'balance' of projects across the six sectors.

In progressing CR&D projects, the innovation related attitudes and behaviours of FI companies start to change, although there may be some resistance along the way given old practices and mindsets. Notwithstanding, some collaborations will progress projects as intended and others may take a different direction (backward or forward), or perhaps even fail. Greater collaboration on projects is expected to lead to new/improved knowledge and technologies that are relevant to addressing challenges in FI. This assumes that key barriers to adoption and diffusion of technologies are addressed and firms have the capacity and skills to implement technologies and process changes.

Over the longer term, the risk of developing resource efficient technologies is reduced (partly due to risk being shared between collaborators) and increased private R&D investment assists in accelerating the development/ adoption of technologies across the FI. Eventually these technologies are expected to reduce resource and energy use in FI. There are various internal and external factors influencing these outcomes and impacts, notably: wider government policy on innovation and sustainability; wider market conditions; actions of international competitors; other programmes, internal business planning/. Also, a key assumption is that the Challenge timescales (2020-24) are sufficient to realise outcomes and impacts.

4. Evaluation research questions

4.1 This section presents the agreed list of evaluation research questions.

Introduction

4.2 The evaluation specification included a longlist of fourteen impact evaluation questions and twelve process evaluation questions. This list has been refined by SQW during the scoping phase, in agreement with the evaluation Steering Group, to ensure the evaluation can focus resources on key priorities. Through consultation with TFI ISCF stakeholders and consideration at a workshop with the TFI team, the list has been streamlined to include the key impact and process evaluation questions, as shown in the tables below.

Impact evaluation questions

4.3 Table 4-1 sets out the agreed impact evaluation questions. These reflect the key aims of the programme, namely increasing competitiveness (through increasing innovation) and improving sustainability (by minimising environmental impacts). The questions also address the key areas of focus of the programme, that is collaboration between businesses, and industry and academia, improving skills and increasing levels of investment in R&D. The questions are applicable to the programme in its entirety but the workstreams most relevant to each question are indicated in the table. Details on workstreams are provided in section 3 (see Table 3-1).

Table 4-1: Impact evaluation questions

#	To what extent and how did the Challenge…	Relevant workstreams (in addition to programme level assessment)
1	Accelerate and facilitate innovation across the Foundation Industries?	1, 2, 3 and 4
1a	Increase multi/inter disciplinary research and innovation across the Foundation Industries?	1, 2, 3 and 4
1b	Increase collaboration across the FI including develop closer academic/industry links?	1, 2, 3 and 4
1c	Accelerate growth of new technology, products and services and fast-growing businesses across the value chain?	1, 2 and 5
2	Minimise environmental impacts by reducing consumption (material resource and energy)?	1, 2, 3, 4 and 5
3	Create more diverse and skilled (technical / managerial / innovation) jobs in the FI?	1, 3, 4 and 5
4	Increase R&D investment in the FI in the UK? From: • Private (including overseas) • Public	1, 2, 3 and 5

Source: SQW and UKRI ITT document

Process evaluation questions

4.4 Table 4-2 sets out the agreed process evaluation questions. The questions focus on the core process issues of how design and delivery help to achieve change. They also consider issues of particular interest to the TFI Challenge including synergies between the workstreams, alignment to needs of industry, and collaboration between businesses, and between industry and academia. The process questions are applicable across the programme, but the collaboration questions are relevant to specific workstreams, as indicated in the table below (for details on workstreams see Table 3-1).

Table 4-2: Process evaluation questions

#	To what extent and how did the Challenge…	Relevant workstreams (in addition to programme level assessment)
1	Has the intended design and delivery of the programme enabled the programme to achieve its objectives?	All workstreams
2	Did the programme meet its target outputs efficiently and effectively?	All workstreams
3	How effectively do the different strands of the programme work together and makes the programme as a whole more effective as opposed to delivering individual strands?	All workstreams
4	Is the programme sufficiently aligned to industrial needs (and consumer needs if relevant)?	All workstreams
5	To what extent and how has the set up and delivery of the programme encouraged the collaboration (or partnerships) of businesses and academics?	2, 3 and 4.
6	To what extent and how has the set up and delivery of the programme encouraged collaboration of businesses of different sizes?	1, 2 and 3.

Source: SQW and UKRI ITT document

5. Key indicators

5.1 This section presents a list of indicators important for evaluating the performance of the TFI programme. The indicators correspond with the outcomes and impacts contained in the logic model (section 3), as well as the key evaluation questions for the programme (section 4). Thus, the focus of this section is on evidencing outcomes and impacts rather than monitoring of outputs relating to the activities for the five workstreams. A set of indicators relating to the inputs, activities, outputs of the programme can be found in Annex D.

5.2 The indicators presented here (and Annex D) refine and add to those presented in our Positioning Paper and discussed at the workshop with UKRI. It is also worth noting that the Challenge is still developing its data monitoring and collection processes. Grant recipients will be monitored using standard UKRI monitoring processes but the remaining workstreams do not have clear plans in place. This represents an opportunity to align programme and evaluation data collection processes to maximise efficiency. We suggest that the indicators in Annex D are incorporated into the monitoring processes of the Challenge.

5.3 Table 5-1 identifies the outcome and impact indicators, the data source, who would be responsible for collecting the data, and how they align with the programme logic model and/or the evaluation research questions. In setting out the indicators in this way, the aim is to ensure the indicators are relevant, appropriate and proportionate to understanding if and how the Challenge contributes to transforming the UK's FI so that they are internationally competitive and environmentally sustainable. We further highlight that these indicators:

- relate to innovation activity, R&D investment, business performance, environmental sustainability, skills
- take into account the long-time lags for innovations to occur in FI, and so we have incorporated intermediate measures as well as longer-term measures
- represent a long list due to the need to cover many of the key outcomes and impacts in the logic model (incl. similar indicators across different programme workstreams).

5.4 More importantly, we do not know how comprehensively and readily we will be able to measure some of the indicators, and so the planned consultation process will seek to obtain a rounded view of evidence that indicates progress, for example on collaborative activity.

Table 5-1: Key indicators

#	Indicator	Source	Responsibility	Outcome/ impact as per TFI programme logic model	Reported	Research Question
Outcomes						
1.	Operationally sustainable glass facility (W1)	Programme monitoring (looking at public and private funding e.g. membership scheme)	UKRI	Increased demand for the glass facility including use by other FI (WI)	Impact report	1
2.	Level of usage by member organisation of glass facility (days) (W1)	Programme monitoring (in Glass Futures KPIs), consultations with stakeholders	UKRI, SQW	Increasing demand for the glass facility including use by other FI (WI)	Impact report	1
3.	Technologies accelerated to market (TRL progression) (W2)	Programme monitoring (at project closure (currently) and more frequently (as delivery progresses).	UKRI	Technologies accelerated to market (W2)	Impact report (recognising may not be significant change in programme timeframe)	1, 1c
4.	Number of new technologies developed (W3)	Programme monitoring	UKRI	New technologies developed to solve cross sector issues (W3)	As above	1, 1c
5.	Number of papers published relating to research on FI (W3)	Programme monitoring (in KPIs for Network+, Hub)	UKRI	Papers published relating to research on FI (W3)	As above	1a, 1b
6.	Number of patents generated on innovation related to FI (W3)	Programme monitoring (at project closure)	UKRI	Patents generated on innovation related to FI (W3)	As above	1a, 1b
7.	Patent applications (W3)	Secondary dataset: OECD patents by technology (for context not programme data)	SQW	Patents generated on innovation related to FI (W3)	As above	1a, 1b

#	Indicator	Source	Responsibility	Outcome/ impact as per TFI programme logic model	Reported	Research Question
8.	Establishment of a shared FI identity (perceptions of internal FI and external stakeholders)	Consultations with participating firms, academics and other stakeholders (using Likert scale question about identity and/or cohesiveness); survey of companies.	SQW	Foundation industries identity established (W4)	Impact report	1b
9.	Willingness among FI companies to innovate	Survey of companies, consultations with participating firms, academics and other stakeholders (including asking for relative importance of innovation compared to other business priorities)	SQW	Increased interest in innovation (WS 1-4)	Baseline and impact report	1a, 1b
10	Willingness among FI companies to collaborate	Survey of companies, consultations with participating firms, academics and other stakeholders (including asking relative importance to other priorities)	SQW	Increased interest in collaboration (WS 1-4)	Baseline and impact report	1a, 1b
11	Willingness among FI companies and academics to collaborate	Survey of companies, consultations with participating firms, academics and other stakeholders (including asking relative importance to other priorities)	SQW	Increased interest in collaboration (WS 1-4)	Baseline and impact report	1a, 1b
	Impacts					
12	Number of new collaborations between companies across FI and with the academic base	Programme monitoring	UKRI	New and effective collaborations across the sectors and with the academic base	Impact report	1a, 1b

#	Indicator	Source	Responsibility	Outcome/ impact as per TFI programme logic model	Reported	Research Question
13	Value of private R&D investment on activity supported by the Challenge (£)	Programme monitoring (by WS); consultations with participating firms; end of programme surveys	UKRI, SQW	Increased private R&D investment (incl. capital investment)	Impact report	4
14	Value of private R&D investment at firm-level (£) (evidence for programme and context)	Baseline and end of programme surveys; secondary dataset	UKRI, SQW	Increased private R&D investment (incl. capital investment)	Baseline and impact report	4
15	Value of private R&D investment at wider sector level (£) (for context)	Secondary dataset	SQW	Increased private R&D investment (incl. capital investment)	Baseline and impact report	4
16	Value of private R&D investment/GVA (for context)	Secondary dataset (explore Beauhurst, potentially FAME database)	SQW	Increased private R&D investment (incl. capital investment)	Baseline and impact report	4
17	Value of foreign direct investment (FDI) secured by the Challenge (£)	Programme monitoring (by WS); consultations with participating firms, survey	UKRI, SQW	Increased FDI in the UK	Impact report	4
18	Value of FDI secured at firm level (£) (for context)	Potentially secondary dataset (2 digit SIC code) (Beauhurst); survey	SQW	Increased FDI in the UK	Baseline and impact report	4
19	Value of FDI secured at wider sector level (£) (for context)	Secondary dataset	SQW	Increased FDI in the UK	Baseline and impact report	4
20	Value of FDI/GVA (£) (for context)	Secondary dataset	SQW	Increased FDI in the UK	Baseline and impact report	4

#	Indicator	Source	Responsibility	Outcome/ impact as per TFI programme logic model	Reported	Research Question
21	Technologies developed and adopted across the FI – progression through TRLs	Programme monitoring	UKRI	Development and adoption of innovations/technologies accelerated across the FI	Impact report	1, 1c
22	Amount of material used by industry	Programme monitoring (asking if project would lead to % reduction in amount of material used. Note, challenging to standardise across firms using different materials so may quantify by type of material).	UKRI	Reduction in the use of resource and energy	Impact report	2
23	Energy consumption by industry	Secondary dataset: ONS, energy use by industry, source	SQW	Reduction in the use of resource and energy	Baseline and impact report	2
24	Emissions intensity (GHG emissions per real unit of GVA)	Secondary dataset: ONS Environmental Accounts	SQW	Reduced carbon emissions	Baseline and impact report	2
25	Number of skills shortages (vacancies) at firm level	Baseline and end of programme surveys	UKRI, SQW	Improved skills across FI	Impact report	3
26	Incidence of skills shortages (vacancies) at sector level	Secondary dataset: Department for Education, Employer Skills Survey	SQW	Improved skills across FI	Impact report	3
27	Senior management have a plan/ taking action on innovation and net-zero	Consultations with participating firms; baseline and end of programme surveys	SQW	Improved skills across FI	Baseline and impact report	3
28	Senior management have the skills to deliver	Consultations with participating firms; baseline and end of programme surveys	SQW	Improved skills across FI	Baseline and impact report	3

#	Indicator	Source	Responsibility	Outcome/ impact as per TFI programme logic model	Reported	Research Question
	innovation and net-zero successfully					
29	Employment by sector	Baseline and end of programme surveys; programme monitoring; secondary datasets: ONS Annual Business Survey, Working Future (Department for Education), Business Register and Employment Survey (ONS)	UKRI, SQW	Improved business performance/growth	Baseline and impact report	1, 1c
30	Value of turnover (£)	Baseline and end of programme surveys; programme monitoring; secondary datasets (from FAME database if UKRI can provide access): ONS Annual Business Survey	UKRI, SQW	Improved business performance/growth	Baseline and impact report	1, 1c
31	Gross operating profit (£)	Baseline and end of programme surveys; programme monitoring	UKRI, SQW	Improved business performance/growth	Baseline and impact report	1, 1c
32	Gross operating surplus (GVA minus employment costs) (£)	Secondary dataset: ONS Annual Business Survey	SQW	Improved business performance/growth	Baseline and impact report	1, 1c
33	Share of exports in total turnover (%)	Baseline and end of programme surveys; programme monitoring (not asked yet as not relevant); secondary datasets: Eurostat Comext	UKRI, SQW	Improved business performance/growth	Baseline and impact report	1, 1c

#	Indicator	Source	Responsibility	Outcome/ impact as per TFI programme logic model	Reported	Research Question
34	Export market share (UK as a share of global exports)	secondary datasets: calculated from Eurostat Comext, UN Comtrade and Annual Business Survey (ONS)	UKRI, SQW	Improved business performance/growth	Baseline and impact report	1, 1c

Challenge-level indicators

5.5 At the Challenge level, and in relation to the overall Challenge objectives, we have identified seven indicators as shown in Table 5-2. These will form the focus of assessing whether the Challenge has achieved what it set out to do. The other indicators in Table 5-1 are important in helping to measure progress, assess changes in the contextual conditions that the programme is seeking to change, and to assess why there may be more/less progress.

5.6 Taking into account the above, we highlight the importance of collaboration and shared identity across the FI – glass, metals, paper, ceramics, cement, and chemicals – are developed sectors on their own, so the extent to which the TFI programme brings them together (and be seen externally) as a single entity to address common challenges will be key.

Table 5-2: Challenge-level indicators

#	Indicator
1	Willingness to collaborate between companies across the FI
2	Willingness to collaborate between industry and research base
3	Number of technologies developed and adopted across the FI
4	Establishment of a shared FI identity (perceptions of internal FI and external stakeholders)
5	Value of private R&D investment in FI (£)
6	Resource and energy usage
7	Senior management have the skills to deliver innovation and net-zero

Source: SQW

6. Evaluation approach

6.1 This section sets out the proposed approach to the evaluation of the TFI programme. It identifies some of the key characteristics of the programme, the wider system in which it operates, and the methodological challenges. This helps to understand the programme from an evaluation perspective and identify the most suitable approach and research methods. The overall approach and a summary of the methods are presented with further details given in section 7 (process evaluation) and section 8 (impact evaluation). The selected approach and methods have been informed by the evaluation literature and guidance, review of programme documentation, and our scoping discussions with stakeholders, and workshops with UKRI.

The TFI programme seen through a complexity 'lens'

6.2 The TFI programme can be described as exhibiting some of the characteristics of a 'complicated' and 'complex' intervention as identified in the evaluation literature.[17] As set out in the logic model and theory of change (see section 3), there is wide variation in the nature (and duration) of support, level of engagement, delivery model, and sectors. The programme has multiple components and organisations, and multiple simultaneous and/or alternative causal strands, and emergent outcomes (i.e. cannot be fully controlled or predicted in advance). These non-linear routes to impact, feedback loops relating to the innovation process, and other characteristics can influence the nature and size of benefits and when these are likely to occur. Also, the programme operates in a wider system which is itself complex and likely to influence its performance. This complexity can give rise to a number of challenges for evaluation, most notably in determining attribution/ causality of the TFI programme. To deal with complexity in evaluation, the Magenta Book (2020) identifies a number of approaches and methods that can be used. It suggests that approaches are selected based on consideration of three inter-related factors: evaluation purpose, system attributes, and the feasibility of evaluation design.

Methodological challenges in evaluating the TFI programme

6.3 There are numerous challenges that have been considered in the design of the evaluation framework. These include 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, and the difficulties in attributing outcomes to the programme in light of multiple external influences. There are further challenges that we highlight, as follows.

[17] Magenta Book (2020) *Supplementary Guide: Handling Complexity in Policy Evaluation*. See also, Rogers, P., (2008) *Using Programme Theory to Evaluate Complicated and Complex Aspects of Interventions*, Evaluation, Vol. 14 No. 1.

6.4 **The amount of public investment in the TFI programme at £66m, is relatively small in comparison to the size of the sectors**. This poses a challenge to detecting changes in headline indicators (e.g. improved business performance in terms of jobs and turnover) as well as intermediate outcomes such as the number of technologies accelerated to market and the number of new technologies developed. Therefore, it will be important for the evaluation to evidence changes in innovation behaviours and R&D investment, and it is expected that the £66m could translate into more investment through crowding in (£83m from the private sector).

6.5 **A number of issues need to be considered in developing appropriate counterfactual(s) for the TFI programme.** The number of firms and other organisations involved in each of the five workstreams of the TFI programme is relatively small. The projects funded (e.g. through CR&D projects) will involve multiple beneficiaries and there may be overlap in these beneficiaries. The small numbers involved will put constraints on statistical work at the level of programme workstreams i.e. sample size required to find statistically significant effects. Selection bias will be a confounding factor in the performance of businesses applying, and attribution bias from interviews/surveys could also give the TFI programme more importance than it deserves. To mitigate these issues, we have proposed a theory-based approach to assess causality or contribution of the programme. This will assess the factors that are important to achieving outcomes.

6.6 The effects of COVID-19, the UK's trade settlement with the European Union (EU), and other wider conditions (e.g. Net Zero) on each of the six sectors are likely to be significant. This may make it challenging to isolate the effects of the programme from these external shocks/ conditions. For example, our scoping discussions identified adverse effects on FI supply chains, operational capacity, and manufacturing activities resulting in reduced demand for FI products. These pressures on businesses may reduce their capacity to engage in planning and investment in research and innovation, potentially reducing their interest in the TFI programme. In light of these wider influences, which are likely to have profound effects on economy and society, the evaluation will respond flexibly and constructively to support learning. We are undertaking scenario work as part of the baseline stage, which will be useful for the programme team as well as providing a tool for the evaluation.

6.7 The drivers and the barriers to innovation and sustainability in FI Innovation will influence the effectiveness of the TFI programme. Some of the barriers to innovation in FI are historical and structural, for example: innovation is uneven throughout the FI; there is a widespread reluctance to adopt novel, unproven technologies, with innovation mainly focused on new to firm rather than new to market; innovation collaboration in FI is not widespread; and increasing energy and resource efficiency is not a key consideration for innovation. In contrast, the drivers to innovation such as maintaining international competitive advantage, reducing costs, increasing production capacity will need to be enabled in FI going forward. The implication is that the evaluation framework and its implementation should be used to inform programme delivery over time and not just be used to measure performance at the

end of the evaluation period. Learning from the evaluation is as important as measuring impact.

6.8 **The timing and mechanisms of the TFI programme will determine how delivery contribute to achieving programme objectives**. In practice, the programme started in late 2019, with variation in timings between the five workstreams (some workstreams commenced later). This means that the delivery structures, approaches, monitoring etc. (at programme and workstream levels) are still evolving. There are a few implications of the above. First, the construction of the baseline position against which to measure the performance of the programme will vary. We will therefore seek to gather data that is relevant for each workstream and at Challenge level (i.e. when it was announced). Second, we will inform lessons on how the mechanisms have been designed in ways that facilitate outcomes and impacts, and also on delivery. This should give scope for making refinements over the remaining time of the programme. It will also be important to consider contextual changes and how the programme could also respond to these. The interim evaluation in 2022 will cover processes and delivery (including how the delivery mechanisms are facilitating progress), and progress towards achieving outcomes and impacts within the wider context. This will draw on multiple perspectives: delivery interviews, monitoring data analysis, an initial round of project/workstream-based interviews and case studies, and wider stakeholder interviews.

6.9 Considering these challenges, the complex nature of both the TFI programme and wider system/context in which it is being implemented, we set out our overall approach below.

Overall approach to the evaluation

6.10 We propose a **theory-based approach** 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 3. We will use **Contribution Analysis** (CA) – a particular theory-based approach – to test the evidence on outcomes and impacts (and underlying assumptions), whilst considering other factors which may have contributed to these benefits (see also box below). Our approach will draw on both qualitative and quantitative data. This will include a range of: 'top down' methods that will provide contextual evidence on change in FI and the innovation landscape; and 'bottom up' methods that will provide evidence on performance, in terms of TFI workstreams/projects and the programme as a whole. The research methods summarised in Figure 6-1 include:

- *Top-down methods* – analysis of sector indicators from secondary data; telephone survey with companies across the FI; modelling of economic and environmental change; scenario analysis of 'plausible' futures for the FI; and in-depth telephone interviews with wider stakeholders.
- *Bottom-up methods* – analysis of applicant and monitoring data; in-depth telephone interviews with the TFI delivery team; a programme of in-depth telephone interviews

with companies, glass facility staff and users, academic researchers, investors, and non-beneficiaries (companies and academic researchers); case studies covering the programme workstreams; potential econometric analysis of impacts; and a technology assessment as an extra option.

6.11 We will also undertake a series of workshops to test and inform the evaluation design, scenario analysis, and interim and final evaluation findings.

6.12 A table mapping how the evaluation methods provide evidence against the research questions is shown below.

Table 6-1: Mapping of evaluation methods against research questions

Method	Process questions	Impact questions
Top-down approaches		
Analysis of sector indicators from secondary data		1, 1a, 1b, 1c, 4
CATI survey with companies across the FI		1, 1a, 1b, 1c, 2, 3, 4
Modelling of economic and environmental change		2, 4
International comparison		2, 4
Scenario analysis of 'plausible' futures	1, 4	1, 1a, 1b, 1c, 2, 3, 4
In-depth telephone interviews with wider stakeholders	1, 4, 5, 6	1, 1a, 1b, 1c, 2, 3, 4
Case studies (process and impact)	1, 2, 3, 4, 5, 6	1, 1a, 1b, 1c, 2, 3, 4
Workshops	1, 3, 4	1, 1a, 1b, 1c, 2, 3, 4
Bottom-up approaches		
Analysis of applicant and monitoring data	1, 2, 5, 6	1, 1a, 1b, 1c, 2, 3, 4
In-depth telephone interviews with TFI delivery team	1, 2, 3, 4, 5, 6	1, 4
In-depth telephone interviews with companies (beneficiary and unsuccessful applicants)	1, 4	1, 1a, 1b, 1c, 3, 4
In-depth telephone interviews with glass facility & users (beneficiary and non-beneficiary)	1, 4	1, 1b, 3
In-depth telephone interviews with academic researchers (beneficiary and unsuccessful app)	1, 4	1, 1a, 1b, 1c, 3, 4
In-depth telephone interviews with investors (beneficiary and non-beneficiary)	1, 4	1, 1c, 4
Econometric analysis (to be decided in 2023)		1, 1a, 1b, 1c 2, 4

Source: SQW

Counterfactual approaches

6.13 In developing the approach to the impact evaluation, we propose to undertake counterfactual analysis for each of the five workstreams where possible, as set out in Table 6-2. It is important to highlight that these are: qualitative/ descriptive analysis or self-reported evidence (not econometric analysis); dependent on the availability of applicant and monitoring data) and will require further discussion with UKRI on what is practically feasible. Notwithstanding these issues, the counterfactual assessment will be used to inform the contribution story.

Table 6-2: Possible counterfactual at workstream level

TFI workstream	Counterfactual
W1: Pilot facility for the glass sector	• Interviews with glass sector stakeholders and companies engaged and not engaged with the pilot facility • Identify investment behaviours and perceptions of skills of the workforce
W2: CR&D competitions/ projects	• Survey of successful and unsuccessful applicants • Assess the effects on key evaluation metrics: collaborations with companies and the research base, R&D investment, energy and resource use, etc. (see indicators in section 5)
W3: Academic-industry competitions/ Projects	• Survey of successful and unsuccessful applicants • Compare university departments/research institutes in FI benefitting from TFI programme vs others (or those benefiting less), to consider: ➢ research grants relating to FI ➢ collaborations with companies in FI ➢ compare baseline to final position to gauge change
W4: Establishing the FI as a sector	• Interviews with stakeholders and case studies – how would FI identity have developed, if at all, without TFI programme? • Survey of companies in FI to gather perceptions
W5: Late-stage finance for companies	• Interviews with investors in the sector – on the TFI programme and wider • Potential to compare SMEs benefiting from the programme with those that have not (interviews or potentially secondary data).

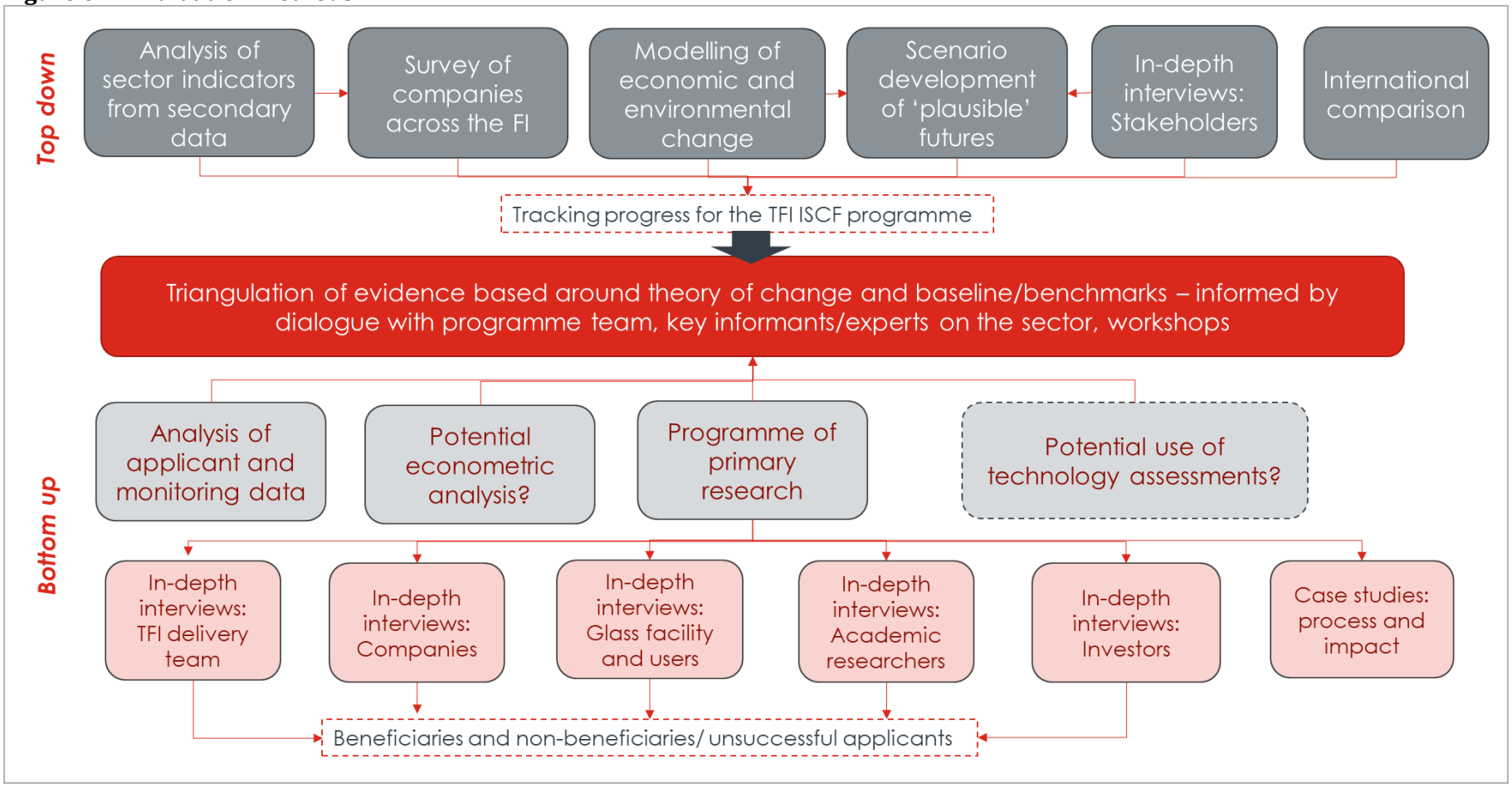
Source: SQW

6.14 We will also undertake counterfactual analysis at the Challenge level (see section 8 for details) through international comparison in terms of how the UK landscape and key intermediate indicators have changed in relation to selected comparator countries (this is contextual and not an empirical counterfactual).

6.15 There is potential to conduct Challenge level counterfactual analysis through econometrics analysis comparing all companies engaged in the Challenge with those that are not, using as comparator groups: unsuccessful applicants and secondary datasets. The possible role of this strand of research is discussed further in section 8. However, feasibility of this approach should be re-examined at the outset of the impact evaluation in light of the number of Challenge beneficiaries.

6.16 The evidence from the top down and bottom-up methods will be triangulated and analysed against the logic model/ theory of change (as described in section 3) and the baseline to arrive at a plausible contribution of the TFI programme relative to other factors, by the end of the programme in 2024, and the implications for potential longer-term impacts.

Figure 6-1: Evaluation methods



Source: SQW. Note: inclusion of the econometric analysis is subject to review at the outset of the impact evaluation (see section 8)

Developing the 'contribution story'…

6.17 As outlined above, the evaluation design is based on an overall theory-based framework, to investigate net outcomes and impacts by exploring the causal chains thought to bring about change by an intervention. This approach is explicitly concerned with both the extent of the change and why the change occurs. In addition, it often considers the context in which the intervention is being implemented (Magenta Book, 2020).[18] The evaluation will draw on the principles and steps of a specific theory-based approach: Contribution Analysis.

Contribution Analysis

CA is a theory-based evaluation approach that "aims to define the links between each element of a logic model, and test and refine these theoretical links between the programme and the expected impacts. It provides a framework for analysing not just whether the programme has had an impact, but how that impact materialised and whether any particular element of the programme or contextual factors were crucial to the impact".[19]

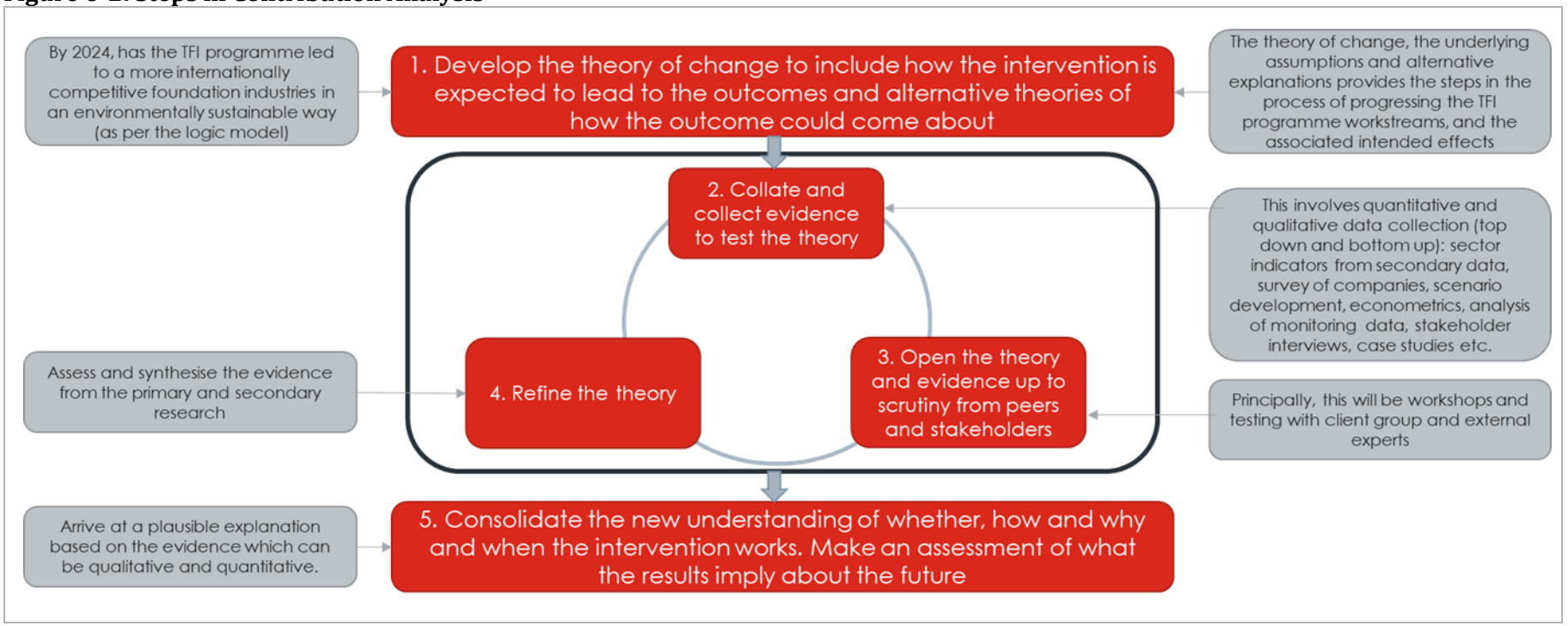
CA can increase confidence that the intervention has had an impact: instead of developing a picture of what would have happened in the absence of the intervention (which is often difficult to determine for complex interventions), CA focuses on whether there is strong evidence that the intervention rather than something else was critical in causing the benefits observed.[20] It, therefore, puts the onus on the intervention. CA draws on the development of logic models and underlying theory of change as to how intended outcomes and impacts came to materialise. The supporting evidence collected is used to prove the intervention made the difference by constructing a 'contribution story' on the extent to which the intervention was important in generating these observed outcomes and impacts relative to other factors.

These other factors could be internal or external the intervention, for example: wider government policy influences innovation and sustainability e.g. incentives to reduce energy use; other innovation programmes accessed by TFI ISCF programme beneficiaries; sector-specific market conditions (e.g. firm characteristics, market structure, regulations, and industry-specific shocks); internal business factors.

[18] HM Treasury (2020) *Magenta Book - Central Government guidance on evaluation*.
[19] Innovate UK (2018) Evaluation Framework. *How we assess our impact on business and the economy.*
[20] Befani, B., and Mayne, J., (2014) *Process Tracing and Contribution Analysis: A Combined Approach to Generative Causal inference for Impact Evaluation*, IDS Bulletin, Vol. 45 No. 6.

6.18 Informed by the Magenta Book, the steps in applying CA are set out in **Error! Reference source not found.**

Figure 6-2: Steps in Contribution Analysis



Source: HMT Magenta Book (2020); SQW

7. Methodology: Process evaluation

7.1 This section provides a detailed explanation of the methods that will be used for the process evaluation.

Purpose of process evaluation

7.2 Process evaluation focuses on what can be learned from delivery of an intervention, particularly what worked well or less well, and why, and what could be improved. Such exploration of delivery also supports the impact evaluation, providing insights into the different routes by which change was achieved for different groups under different circumstances. Process evaluation evidence thus helps to build the contribution story.

7.3 The TFI Challenge evaluation will have separate phases for the process and impact evaluations, although the impact evaluation will draw on the findings of the process evaluation. The process evaluation phase is scheduled for 2022. The purpose of that phase is threefold:

- to assess how the design and delivery of the programme have contributed to achieving objectives to date and are facilitating the progress towards realising outcomes and impacts as identified in the programme's theory of change. This will require interim measurement of progress against key indicators
- to identify and consider wider contextual factors that may influence how effectively activities are being delivered, for example new environmental standards, wider technological and policy developments, and changes in international competitiveness
- to gather learning that can be used by the programme to refine its activities during the remaining timeframe, for instance, identification of any barriers or facilitators to impact and how they may be managed or overcome.

Process evaluation questions

7.4 As described in section 4, the core focus of the process evaluation questions is the design and delivery of the programme. However, the questions also seek to explore areas of particular interest to the TFI Challenge, namely synergies between the different workstreams, alignment to needs of industry, and collaboration between businesses and between industry and academia.

Process evaluation methods

7.5 The process evaluation will draw on a range of qualitative and quantitative research methods, as detailed below.

Review of programme documents

Purpose: To provide the evaluation with key information regarding the design and delivery of the programme. This documentary evidence forms the basis for the other research and analysis.

7.6 The scoping stage and the development of this Evaluation Framework incorporated a document review which will be built upon during the baseline and interim phases for the process evaluation. The document review will include programme materials and wider ISCF documents where relevant, including:

- Any updates to the programme delivery plan
- Updates to the bi-monthly Programme Board meetings
- Any updates to other core programme documents such as the logic model, workstream KPIs and stakeholder mapping
- Workstream specific documents such as competition calls, application forms and assessments of applications.

7.7 For the purpose of the process evaluation, analysis of such documents will focus on the nature of activities being delivered, profile of organisations engaged and unsuccessful applicants, collaboration within industry and between industry and academia, the nature of technologies/innovations being pursued and so on.

Review and analysis of monitoring data

Purpose: To track progress against delivery plans and consider the coverage and quality of monitoring data.

7.8 In parallel with the document review, we will assess available monitoring data to track progress against key project and programme level indicators. Some monitoring processes are in place while others are in development. Progress against outputs will be reported in the bi-monthly Programme Board reports: we will access underpinning data as required. This is likely to include:

- Extracts from a UKRI database regarding project applications
- Extracts from a UKRI database regarding data collected from Monitoring Officers for competitive funded projects
- Information from EPSRC regarding Hub and Network+ related projects.

7.9 The process evaluation will also consider the coverage and quality of monitoring data. While it is not the role of the evaluation to collect or verify programme monitoring data, it will be important to identify any major issues or gaps in the evidence base at this stage and include this in the interim report so that the TFI team can take any necessary action to ensure data will be available for the final impact evaluation phase.

Consultations

Purpose: To provide primary evidence on the appropriateness of programme design and the effectiveness of programme delivery from those involved with or aware of the programme.

7.10 **We will undertake 75 in-depth interviews as part of the process evaluation** to gather perspectives on design, delivery and progress to date towards realising outcomes with a range of stakeholders, including those delivering and those participating in the Challenge, plus some individuals not directly involved but with knowledge of the FI. Specifically, we plan to undertake the following interviews, lasting 45 to 60 minutes:

- delivery team (x10)
- companies (beneficiaries) (x20)
- glass facility & users (x10)
- academic researchers (x10)
- investors (x5)
- wider stakeholders (x20).

7.11 Sampling will be discussed in more detail with the client group during the process evaluation, but we envisage using the following characteristics in selection: sub-sector, business size, and geography. Given the focus in the consultations is about learning, we propose focusing on participants with a greater level of involvement in Challenge activities (except for the wider stakeholders).

7.12 We will design and share research tools for the interviews with the client group for review and revise according to feedback. While the six process evaluation questions will be relevant to all interviewees, the focus of the interviews will be tailored to the different groups and their involvement with the programme. The main areas of focus for each group are shown in the table below.

Table 7-1: Areas of focus for different groups of interviewees for the process evaluation

Delivery team (x10)	Beneficiary companies (x20)
• Progress against delivery plans • Reasons for divergence against plans or revisions to plans • Appropriateness of programme design • Effectiveness of delivery structures • Synergies between workstreams • Effectiveness of management and governance • Effectiveness of data collection and management • Alignment to industry needs • Collaboration within industry, and between businesses and academia • Challenges and enablers • Learning to date	• Expectations of programme • Experience of participation (including promotion of programme, application processes, monitoring processes, and involvement in more than one workstream if relevant) • Alignment to industry needs • Experience of collaboration with other businesses and/or academia • Learning - what works well (or less well) and why • Recommendations for programme development
Academic researchers (x10)	**Glass facility and users (x10)**
• Expectations of programme • Experience of participation (including application processes, monitoring processes, and involvement in more than one workstream if relevant) • Experience of collaboration with businesses and/or other academics • Learning - what works well (or less well) and why • Recommendations for programme development	• Expectations of programme • Experience of participation (including promotion of glass facility, application/membership processes, monitoring processes, and involvement in other workstreams if relevant) • Alignment to industry needs • Experience of collaboration with other businesses and/or academia • Learning - what works well (or less well) and why • Recommendations for programme development
Investors (x5)	**Wider stakeholders (x20)**
• Expectations of programme • Experience of participation (including promotion of programme, application processes, monitoring processes, and involvement in other workstreams if relevant) • Assessment of programme alignment to business needs • Learning - what works well (or less well) and why • Recommendations for programme development	• Expectations of programme • Appropriateness of programme design • Alignment to industry needs • Perspective on degree of collaboration within industry, between businesses and academia, and across sectors through programme • Relevant contextual changes • Recommendations for programme development

Source: SQW

7.13 The analysis of the consultations will be undertaken using the specialist software package MaxQDA, which allows text to be systematically tagged with codes aligned to the process evaluation questions and emerging themes.

Case studies

7.14 Interviews with beneficiary companies will developed into case study summaries (c. 1 to 2 pages) outlining how design and delivery have contributed to achieving objectives to date. The case study summaries will provide richer insights into the experience of businesses participating in the programme and offer potential for learning about what works (and doesn't) to inform programme delivery for the remaining timeframe. The case studies will be structured according to the logic model.

Validation workshops

Purpose: To present and test the findings on process and progress to date with the client group and other stakeholders.

7.15 Draft findings from analysis of the process evaluation evidence will be presented at two separate workshops with the client group and other invited individuals (e.g. interviewees, wider stakeholders). Attendees at the workshops will be asked to reflect on findings from several angles including: the process evaluation questions; learning and recommendations for the final stage of programme delivery; and considerations for the impact evaluation. Feedback from the workshops will inform any subsequent analysis and how the findings are framed in the process evaluation report.

Learning

7.16 As the programme progresses with implementation of the different workstreams and puts in place monitoring processes, we recommend that TFI uses those processes to gather learning and periodically review progress against the programme and workstream level logic models. As noted in the introduction to this framework, one of the key purposes of evaluation is to generate learning. Embedding learning processes from the outset can be really valuable in terms of identifying which projects or activities are progressing well (and how) and which ones are not (and why), and those projects with the potential to scale-up and/or influence systems. Moreover, one of the aims of the evaluation is to assess whether delivery and eventual outcomes and impacts amount to 'more than the sum of the five parts' of the TFI programme. This could be supported by periodic consideration of any synergies between workstreams and whether and how activities can be replicated beyond the programme.

7.17 Table 7-2 provides some suggested learning questions. These questions are based on the logic model structure for the workstreams and programmes and wider research on learning

organisations, in particular the 'learning cycle' concept. The questions will help to identify key lessons in three ways: highlighting common learning across the workstreams and programme; identifying projects with the potential to be scaled/replicated, rolled out and influence systems; and informing development of projects in 'real-time'.

Table 7-2: Key questions for learning

Learning cycle stages	Main questions
Concrete experience (i.e. building experience through actions)	• What projects are/have been delivered (incl. type, size, and timing of projects)? • Do the projects align with the rationale for intervention, objectives, inputs, and activities set out in the logic model?
Reflective observation (i.e. reviewing the experience)	• Which projects are progressing well in terms of delivery (and why)? • Which projects are not progressing so well in terms of delivery (and why)?
Abstract hypothesis (i.e. concluding from the experience)	• Is there evidence of progress towards the outputs and outcomes as set out in the logic model? • What have been the key enablers and barriers to date?
Active testing (i.e. planning future action)	• What future action is needed to help inform development projects in real-time (to address any issues and/or to further improve)? • Are there projects which have the potential to be scaled-up, rolled out and influence systems?

Source: SQW; Nesta

7.18 Finally, we will consider reporting key learning in a form that can be taken up the FI and stakeholders as required after the end of the TFI programme.

8. Methodology: Impact evaluation

8.1 This section details the specific research methods – bottom up and top down – that will be used to assess the impacts of the TFI programme (Phase 4 of the evaluation). It also outlines how the data collected will be analysed against the logic model and theory of change.

Bottom-up methods

8.2 **Bottom-up methods provide evidence on performance, in terms of TFI workstreams, projects and the programme as a whole**. In the final impact phase, this will include analysis of applicant and monitoring data; and in-depth telephone interviews with companies, glass facility staff and users, academic researchers, and investors, non-beneficiary companies and academic researchers. In-depth case studies will be undertaken relating to programme workstreams. In addition, we propose a way of undertaking econometric analysis of impacts at a Challenge-level. Further details are provided below.

Analysis of monitoring data and documentation

Purpose: This will involve an analysis of applicant and monitoring data to profile beneficiaries. It will also help to inform an assessment of performance against the inputs, activities, outputs and some outcomes of the logic model. Performance will be compared to expectations, as part of the assessment as to whether the programme is on track to deliver the intended benefits. The analysis will inform other aspects of the impact evaluation (e.g. consultations and case studies) by identifying areas to test such as on key achieved outcomes and areas of over/under-performance.

8.3 This will involve an analysis of applicant and monitoring data covering:

- **Applicant data:** We will analyse data on the different types of applicants - business and academic/ research organisation. We will review competition application data for successful and unsuccessful applicants, as well as the Funders Panel Sheet for competitions (see details in Table 8-1). Also, for funded projects we will analyse qualitative description of the proposed project, intended outcomes. These will be analysed at baseline stage to profile participants and understand the details of projects from different programme workstreams.
- **Monitoring data:** As noted in section 5, the data monitoring and collection processes are currently being put in place with some being planned. We will analyse the monitoring data provided by UKRI to assess progress at and within each workstream), identifying areas of over and underperformance. This will cover:
  - inputs/ expenditure - whether the inputs required met expectations and determine whether assumptions about the programme, such as cost and time, were correct

- activities - to determine whether the programme is being implemented as planned or whether there are any unintended consequences
- outputs - to inform an assessment of whether the programme delivered the target outputs
- outcomes - to measure the short-medium term benefits realised from delivering the outputs, against original targets and expectations

- **Close out reports:** We will analyse any project close out reports available during Phase 4 of the evaluation.[21] This will help to understand what has been achieved on projects against original aims, and potentially indicate any future plans.

8.4 Table 8-1 summarises the key monitoring in place/ planned by UKRI.

Table 8-1: Monitoring in place/ planned by UKRI

Source	Summary	Frequency of data collection
Competition application forms for successful and unsuccessful applicants	Information collected include: project rationale, approach, team members and target market; expected project outputs and impacts; project costings, risks. Note, these will differ according to project competition.	Once at competition application stage
Funders Panel sheet for competitions	Data includes assessor's score, project costs, team details, research category and innovation area for both successful and unsuccessful projects.	Once at competition application stage
Close out reports (Monitoring Officer/Innovation Lead reports)	Data/ reflections on key project activities, including spend to profile and activities completed compared to planned. This also includes due diligence checks and feeds into an Innovate UK database.	Once at project close

Source: SQW; UKRI

8.5 We anticipate engaging with representatives of the programme management team, e.g. monitoring officers and innovation leads, to understand any issues and important contextual matters that are relevant to the monitoring data. The close-out reports may also signpost to other key materials outlining achieved outcomes. The monitoring data will also be used to inform selection of interviewees by considering the different levels of engagement in project activities by various organisations.

[21] We would request that UKRI provide close out material in a single integrated Excel spreadsheet.

In-depth interviews

Purpose: In-depth interviews will be undertaken to gather important evidence on the impact evaluation research questions (see section 4). The focus will be on understanding the outcomes and impacts of the programme within and across the FI, how these came about, and the role of the TFI programme in contributing to reported benefits relative to other factors. The interviews will also provide an opportunity to explore any unintended consequences of the programme. The interviews will cover the five workstreams, drawing on a range of perspectives: company beneficiaries, glass facility staff and users, academic researchers, and investors. In addition, interviews will be undertaken with non-beneficiary companies and academics. These interviews will help inform the 'counterfactual' position i.e. what would have happened without the TFI programme.

8.6 **We have allowed for 100 in-depth telephone interviews in the final phase**, indicatively: 30 company beneficiaries; 10 glass facility staff and users; 10 academic researchers; 10 investors; and 20 non-beneficiary companies and academics; 20 wider stakeholders. (in-depth interviews with wider stakeholders are a top-down approach which is discussed later in this section). The selection of the stakeholders will be informed by suggestions from UKRI, our study team experts, and our review of the stakeholder mapping. The stakeholders will cover all six sectors, any cross-sector organisations/ individuals, and those outside the FI.

8.7 We will design detailed research tools for interviews, shared with the client for review and comment before finalising. The structure of these tools will be informed by the TFI programme logic model and the key evaluation research questions. At this stage, we envisage the main topics to be covered with each interviewee group as summarised in Table 8-2.

Table 8-2: Interview groups and topics to be covered

Group	Summary of main topics to be covered

Company beneficiaries	• Key activities and outputs from the TFI programme
	• Key outcomes and impacts achieved (and expected)
	• How the activities and outputs resulted in the outcomes/impacts reported
	• Additionality and contribution of the programme to the reported outcomes/ impacts
	  ➢ extent to which these would have been achieved without the programme -evidence of scale/speed/quality benefits
	  ➢ the importance of the programme relative to other factors that have contributed to outcomes/ impacts
	• Any unintended consequences
	• Wider benefits within and cross FIs
	• Overall satisfaction with the programme
	• Any learning/ areas for improvement

Glass facility staff and users	• Level and nature of interest/demand for the facility including from other FI • Operational sustainability of the facility

Group	Summary of main topics to be covered
	• Nature and level of usage of the facility – what would have happened without the facility • Perceptions of skills of the FI workforce engaged and not engaged with the facility
Academic researchers	• Similar topics to company beneficiaries above, but focus on the following: • Developing closer academic and industry links through projects dedicated to technology transfer • Increasing collaboration, evidenced through publication of research papers and patents, between academics and industry to solve common environmental sustainability issues • Increasing the academic standing of FI groups in the UK and transferring research-based technology into the sectors of cement, glass, metals, paper, chemicals and ceramics
Investors	• Similar topics to company beneficiaries above, but focus on the following: • Extent to which the TFI programme accelerated growth of new environmentally sustainable technologies specific to the FI and fast-growing businesses through co-investment with private equity/investors • Increased the number of private equity investors and investment in the FI • Wider views on the private funding environment for sustainable technologies (e.g. level of provision, finance providers, barriers to investment) and how this may impact on the FIs and TFI programme
Non-beneficiary companies	• What has been done without TFI programme funding, e.g. whether activities have been progressed • If so, how this has differed to the proposals submitted for TFI programme funding in terms of scope, scale and speed of delivery
Non-beneficiary academics	• As above, what research activities/ projects have been progressed without TFI programme funding e.g. whether activities have been progressed • If so how and how these are different to the proposals submitted for TFI programme funding.

Source: SQW

8.8 We highlight the following points regarding the in-depth interviews:

- We will undertake analysis of interview data for Challenge-level interviews and for the five workstreams, where appropriate
- The analysis will be structured under the impact evaluation research questions and will use a specialist software package, MaxQDA for the qualitative responses
- We aim to provide any quantifiable estimates of benefits, drawn from the interview data whilst recognising that these may be indicative due to the challenges consultees may have in making claims of attribution and contribution to the programme.

Case studies

Purpose: The case studies will provide an in-depth assessment of outcomes and impacts of workstream activities, how these have been realised, and factors that have enabled or hindered pathways to impact. This will include assessing the direct outcomes for beneficiaries, and wider impacts on the FI: greater collaboration, improved competitiveness and environmental sustainability, shared FI identity etc.

8.9 For the reporting in the final phase, we have allowed for eight case studies (1–2-page summaries) covering the workstreams. These will be write-ups of based on the interviews already undertaken. The cases will be selected to reflect different activities, sectors, mix of companies, academic researchers, and investors. The structure of the case studies will be informed by the logic model and impact evaluation research questions. The case studies will add to the overall contribution story, illustrating how and in what contexts projects were able to generate outcomes and impact.

Challenge-level econometric analysis

8.10 In addition to the research methods described above, we have designed a quasi-experimental approach[22] to the evaluation at the Challenge-level[23] . This will require an assessment of viability at the outset of the impact evaluation given uncertainty on the number of businesses participating and the split by sector). Specifically, the proposed approach **uses econometric based difference-in-difference (DiD) techniques** on selected key outcome variables. DiD is recognised in the Magenta Book as a robust evaluation approach to assessing the counterfactual position[24]. If it is deemed possible to use this approach, it will involve comparing the outcomes observed in supported organisations to the outcomes observed in **two alternative comparison groups**: i) a **wider business population** of non-engaged businesses, and ii) **Unsuccessful Applicants (UA)**.[25]

8.11 It is important to highlight a few key points regarding the quasi-experimental analysis.

- As mentioned in the sections above, there is some uncertainty at this stage around the total number of participating businesses. We anticipate the number to be relatively small, around 100-200 businesses across the five workstreams.

[22] Quasi-experimental approach identifies a comparison group that is as similar as possible to the treatment group in terms of baseline (pre-intervention) characteristics. However, unlike an Randomized Control Trial (RCT), a quasi-experimental design by definition lacks random assignment. Instead, assignment is by means of self-selection (by which participants choose treatment for themselves) or administrator selection (e.g., by officials, policymakers etc) or both routes.

[23] Note, we would want to discuss the econometric analysis method with UKRI including resource implications (this method was outside of our original proposal costings).

[24] This analysis is expected to reach at least level 3 on the Scientific Maryland Scale (SMS). See https://whatworksgrowth.org/resources/the-scientific-maryland-scale/

[25] We will need to check the viability of using UA after estimates on numbers for this group are provided by UKRI.

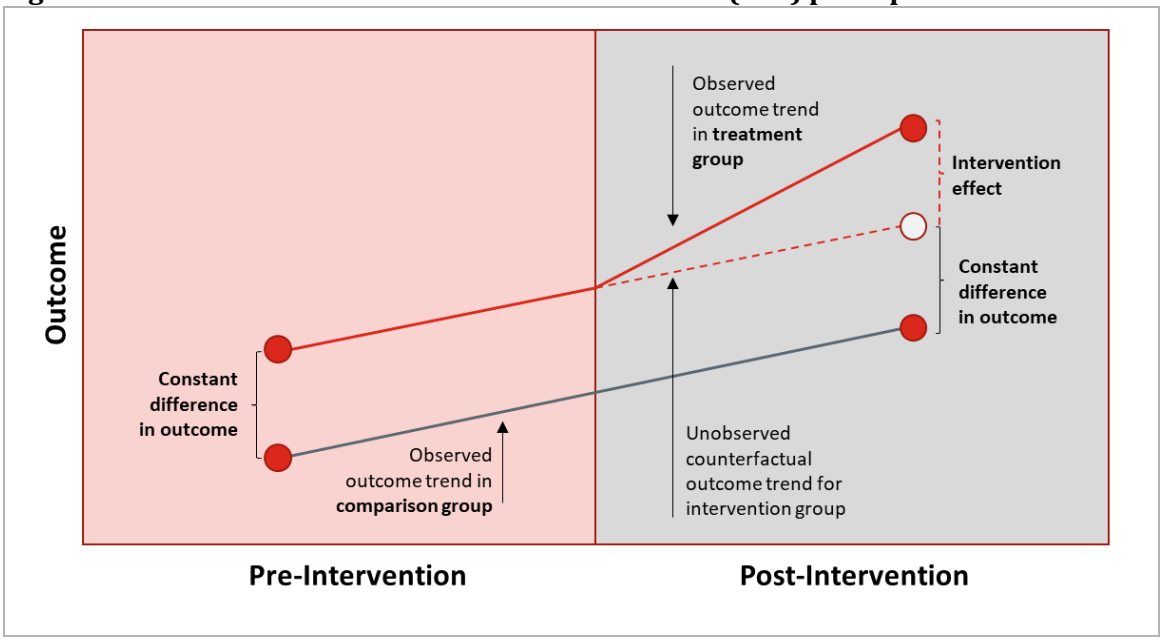
- To maximise the sample size available for the analysis, the data will need to be aggregated across all workstreams. Therefore, the quasi-experimental analysis will provide a summary estimation of the effects of participation in *the Challenge*, not its specific workstreams.
- The analysis will focus on businesses that have been supported by the Challenge only. It will not include the outcome and effects that have been realised for other types of supported organisation (i.e. universities and research institutes).

8.12 Evidence from the quasi-experimental analysis, if undertaken, should be viewed as one part of the wider evidence base, complementing and informing other research methods. The evidence would be triangulated with the wider evidence sources, to inform the Contribution Analysis as part of the overall theory-based approach.

Difference-in-Differences

8.13 A DiD approach will allow us to estimate the effect of support by comparing the outcome measures before and after the intervention across supported (the treatment group) and unsupported (the comparison group) businesses. **Error! Reference source not found.** sets out the approach graphically:

Figure 8-1: Illustration of the difference-in-difference (DiD) principle



Source: SQW / Innovate UK (2018)

8.14 By combining the information from different periods in time across the treatment and comparison groups, DiD accounts for time trends (the dashed red line representing unobserved counterfactual outcome trend for intervention group in the figure above). Therefore, only the changes in the outcome measures observed for the treatment group which exceed the changes observed in the comparison group can be attributed to participation in the programme (intervention effect). This also means DiD estimates of the effect of the

programme are free from the influence of any unobserved business-specific characteristics, as long as those do not change over time.

8.15 The primary assumption behind the DiD approach is that without support from the programme the outcome measures for the treatment group would have followed the same trajectory as those for the comparison group (known as the 'parallel trends' assumption). To examine the validity of this assumption we will undertake graphical analysis of the outcome measures for which timeseries of data is likely to be available such as employment and turnover[26]. A more detailed discussion of the DiD approach, including the specification model is provided in Annex G:.

8.16 The exact statistical model will be finalised following preliminary analysis of the data. However, we expect it to take the following general form:

$$\boldsymbol{Y_{it} = \alpha_i + \gamma_t + TFI_i \cdot time_t + \beta_1^{DD} D_{it} + \beta_2 X_{it} + \varepsilon_{it},}$$

- Y_{it} is the outcome variable of interest for company i in year t
- D_{it} is a variable equal to one when companies are in receipt of support, and zero otherwise
- TFI_i and γ_t are group and time 'fixed effects' which capture the pre-treatment differences between the treatment and comparison groups and account for the influence of any external events which affected everyone in the economy (e.g. the Brexit vote, Covid-19)
- α_i captures all observed and unobserved time-invariant differences between individual companies in the treatment and comparison groups
- $time_t$ is a continuous time trend which needs to be included if the parallel trends assumption appears to be violated (subject to data availability)
- X_{it} is a set of additional control variables (business and project characteristics);
- ε_{it} is a firm-specific error term reflecting the difference between the observed values of the outcome measures and those predicted by the model.
- The coefficient β_1^{DD} represents the DiD estimate for the effect of the challenge.

Comparison groups

8.17 There are several ways to help ensure the treatment and comparison group are as similar as possible and ensure there is no selection bias. One common approach is to construct a

[26] In case the assumption appears to be violated, where feasible, we will attempt to account for the differences in pre-treatment trends between the groups. The observed difference between the basic estimates which do not account for the pre-existing trend differences and the results from the more sophisticated model will inform our approach to correcting the estimates for the outcome measures where a long timeseries will not be available (such as R&D expenditure, R&D intensity (expenditure / turnover), success of R&D).

comparison group from the wider business population using matching techniques. Another approach is to use data from UAs. We discuss both these options here.

Comparison Group 1: A group of non-engaged businesses[27] drawn from the wider business population

8.18 Non-engaged businesses[28] would be identified in secondary datasets such as Business Structure Database (BSD)[29] using Propensity Score Matching (PSM) to ensure the treatment and comparison group are similar. PSM is a statistical technique that estimates the probability of any business being exposed to the treatment (TFI support) based on their observable characteristics. These probabilities, known as propensity scores, are then used to match businesses in the treatment and comparison groups, so each group contains businesses with a similar set of propensity scores. The intention is to remove the effect of those observable characteristics from any analysis of outcomes. The characteristics of businesses which would be used for PSM would include sector, geographical location and pre-treatment employment and turnover[30]. Comparing supported organisations to non-engaged businesses would provide a larger sample size compared to using other comparison groups (e.g. UAs, see below), and improve the robustness of the analysis.

8.19 The BSD draws on official data (not self-reported estimates).[31] As such, analysis using secondary data would provide a more objective estimate of TFI impact and reduce our reliance on self-reported data collected by surveys. Having said that, the BSD is narrow in scope compared to surveys. There are several variables of interest not comprehensively included in the BSD dataset. Relevant outcome variables available in the BSD include only turnover, employment, and productivity (turnover per employee). Other secondary datasets can be considered for the analysis (e.g. Fame[32] by Bureau van Dijk). However, this will have cost implications for the evaluation. It is important to understand that no single secondary data source will cover all outcomes, highlighting the importance of the mixed-methods approach (as discussed above).

8.20 Due to uncertainty around the number of beneficiaries we have not undertaken formal power calculations. At the challenge level we expect there to be between 100 and 200 beneficiaries. Given the comparison group would be drawn from the wider business population we expect the sample size to be large enough for a meaningful statistical analysis. We could undertake

[27] Businesses that have not been involved in TFI as leads/partners/unsuccessful applicants.
[28] Businesses that have not been involved in TFI as leads/partners/unsuccessful applicants
[29] Business Structure Database is released each year and containing data collected through VAT and PAYE records. This provides data on employment and turnover for any company with one or more employees, or earning over £80,000 annual turnover
[29] Businesses that have not been involved in TFP as leads/partners/unsuccessful applicants
[30] These characteristics are available in BSD. Matching on additional characteristics may be possible if multiple data sources are combined.
[31] However, BSD also includes imputed data where there are missing entries.
[32] Fame is based on data filed by companies at Companies House. In theory it covers a wide range of variables which can be found in balance sheets and profit-loss accounts, including profit, employment, exports etc. However, the coverage is relatively patchy since not all companies report all variables and they don't always do it consistently over time.

descriptive analysis by sub-groups and also control for any differences between them (e.g. in terms of average turnover) by using additional variables in the econometric analysis. For the results to be interested as the overall effect of the Challenge, the sample of business beneficiaries would need to be balanced across the six sectors, to the extent possible.

8.21 Additionally, we would utilise data from the baseline and impact survey where possible[33]. As mentioned above, the baseline and impact surveys are expected to target 400 businesses each. At impact evaluation stage, this will cover around 300 non-beneficiaries, some of which will be non-engaged businesses.[34] Sample size permitting, we would be able to test outcomes and impacts covered in the self-reported survey e.g. R&D expenditure, employment, turnover, level of collaborations. In addition, the analysis would explore effects on improved skills as well as environmental impacts.

Comparison Group 2: Unsuccessful applicants (UAs)

8.22 UAs form a good comparison group because they are likely to be similar to the treatment group on a range of observed and unobserved characteristics such as their attitudes towards risk and the scale of participation in R&D and innovation activities. As indicated above, we would need to check the viability of using UA once the estimated number for this group is made available by UKRI. If it is a low number, then the UA approach would not be feasible. Notwithstanding this issue, we set out below details on using UAs.

8.23 Ideally, the comparison group would be constructed using data from projects deemed to be of high quality and fundable, but for which funding was not available (i.e. UAs of high-quality project only). This would increase the observed and unobserved similarities between the treatment and comparison group, enhancing the validity of the comparison group. Projects judged to be of lower quality than successful applicants may have several implications for the validity of the comparison group. For example, the project is less likely to have significant returns, meaning the comparison group would be expected to perform less well than the treatment group. Likewise, the project may be either too early or too late in the innovation journey to be suitable for grant funding. This means the comparison group would have a different returns profile to the treatment group. Unfortunately, due to low expected sample size, using data from only high-quality projects may not be feasible; the analysis using comparison group 2 will use data from all UAs. To account for potential differences in 'quality' between the beneficiaries and UAs as far as possible, we will explore the potential use of additional control variables (e.g. project score). Sample size permitting, we will also explore

[33] Where businesses respond to the Impact Survey only, data will be gathered retrospectively on earlier periods to enable the DiD analysis

[34] We expect the impact survey to cover approximately 100 beneficiaries. The exact composition of the sample will depend on the response rate, however at the sampling stage (when selecting which beneficiaries to contact) we will seek to ensure that the sample is representative of the challenge i.e. that particular types of businesses and the challenge's workstreams are not under or over represented.

restricting the comparison group only to high quality UAs to evaluate robustness of the results.

8.24 Similar to comparison group 1, this analysis would be based on data from two sources. First, UAs would be identified in secondary datasets (i.e. BSD). Second, we would draw on self-reported benefits from the baseline and impact surveys.

Limitations and considerations for the DiD analysis

8.25 The DiD approach outlined above has its limitations, which need to be fully understood, communicated, and, where possible, accounted for as part of an evaluation. These are presented below:

Table 8-3: Limitations and considerations for the DiD analysis

Limitation	Description
Time lags in the secondary datasets	• Lags in availability of data in secondary sources and the expected time-paths to impact for beneficiaries will affect our ability to confidently draw conclusions on the causal effect between the support and business outcomes. • The final impact evaluation will involve fieldwork and analysis in mid-2023, which is likely to be able to draw on information in BSD covering data only to April 2022. As such, the DiD analysis for Comparison Group 1 will provide an early stage perspective on the trends of supported businesses. • In this context, this analysis should be seen as illustrative, and complementary to the other DiD analysis (i.e. using survey data) and wider evaluation research. • That said, once established, it will be possible for the groups to be compared over a longer time-period in on-going or subsequent evaluation research.
Varied coverage of UAs	• Given the data will be pooled across all workstreams to maximise the sample size, it is important to note that there will be no UAs in some workstreams (e.g. W1, W4 and possibly W5). That is, all those who applied for support, received support. • There is a risk that few UAs will participate in the surveys limiting the analysis to variables available in secondary datasets
Outliers	• Both the beneficiary and UA may include some very large businesses, which may potentially skew the results. • This will be addressed via inclusion of a control variable for business size in the regressions, and sensitivity analysis.
Outcomes may vary between leads and partners	• It is possible that the findings for the full groups may mask variation in outcomes realised between leads and partners. • To account for this, an additional control variable will be included in the regressions to see if the impacts do differ between lead and partner applicants.
Some outcomes of interest are not	• This includes outcomes that are categorical (i.e. yes/no, rather than change over time) such as whether there have been improvements of

Limitation	Description
suited for DiD analysis	existing products, services and processes, and the introduction of new products, services and processes to the market. • We will attempt to capture the effect of the programme on these outcomes using a binary dependent variable model (e.g. a probit or logit regression). • Such analysis will reveal whether TFI support is an important factor in increasing the probability of businesses realising these outcomes, relative to the comparison group. This analysis is likely to be applicable only to variables collected through surveys and therefore may be restricted to Comparison Group 1 only due to concerns on the number of UAs captured by the surveys.

8.26 Following peer review, we acknowledge that given the long time horizons for most of the projects in these sectors, the relatively small (and diverse) beneficiary group and the challenges in developing a clear counterfactual group, the value of DiD econometric modelling is likely to be limited. This is particularly the case given the overall timeline for the evaluation. We therefore suggest that econometric analysis described is not undertaken. However, if deemed necessary, we can re-visit this at the start of the impact evaluation in 2023.

Technology assessment (optional)

8.27 The following technology assessment was presented as an option to the TFI client group but it was agreed that it would not add significant value. The description has been left for transparency.

8.28 A technology assessment could be incorporated as part of the bottom-up view. The justification for this and a summary of what it could cover are given below. It is important to note this is an extra option, so we would need to discuss with UKRI the implications for resourcing should UKRI be interested in implementing it.

8.29 As a follow on from the scenario analysis work (see 'top down' sub-section below), consideration was given to how this might provide additional value to UKRI in the context of technology assessment. This is partly motivated by the critical insight from our scenario work that much of the FI sector is predicting a linear future, which is likely to inform their internal technology assessment and impact on proposals. We believe that this could be an important consideration for TFI programme design and delivery. There are a few points in the programme process where we think this might be most applicable.

8.30 **Programme Design:** Technology assessment during the phase of programme design (when specific 'calls' to FI companies and academics are being drafted) are likely to be affected by the trajectory of industry moving away from their Business as Usual (BaU) expectations. The scenarios we have created (see below) could also be used to inform a more robust technology assessment during this phase. This would improve the structure of the calls (e.g. CR&D competitions through workstream 2) to ensure they were robust to alternatives to BaU.

8.31 **Programme Delivery:** In programme delivery we think there are two key moments where the scenarios informed approach to technology assessment can add specific value.

- *Project reviewing process.* Scenarios can improve risk identification based upon the risk specified in the scenarios. They can also test assumptions that are explicit or implicit in the projects.
- *Initial months of winning projects.* During this period, winning consortia will be adding detail to their project plans, and will be including market development and market information in that planning.
  - UKRI investment in the scenarios and background research could be used to inform the detailed business plans that emerge in the early project, and to test them once they have emerged.
  - Business plans for the promised technology would benefit from better understanding of the market, and this is a key moment when the scenarios can help to inform that market understanding early in the project.
  - This helps to ensure that the technology and business plans that are output from a project are more robust to the conditions in which they enter the market.

8.32 We would be pleased to further discuss this option with UKRI, providing further details on how the technology assessment could be applied, thereby informing the design and delivery of the programme in real-time.

Top down methods

8.33 Top down methods provide contextual evidence on change in FI and the innovation landscape. These include: analysis of sector indicators from secondary data; telephone survey with companies across the FI; and in-depth telephone interviews with wider stakeholders; modelling of economic and environmental change; scenario analysis of 'plausible' futures for the FI.

Analysis of sector indicators from secondary data

Purpose: To provide sector-level evidence about the circumstances in which the TFI programme operates, both in terms of the original position when the Challenge was announced, and to contextualise performance during the evaluation. The sector evidence will include economic and environmental indicators from secondary data sources. Understanding wider contextual changes and drivers (taking into account future plausible scenarios) - testing the extent to which these have influenced programme evolution and performance - is important in testing the theory of change and undertaking the Contribution Analysis. The analysis will provide context to the TFI programme and not explain any direct causal links in changes of performance.

8.34 The analysis of the sector indicators from secondary data[35] will provide contextual evidence aligned to the programme's scope and objectives, and specifically on the wider economic and environmental performance of the foundation industries in the UK. Data will be gathered and analysed at three points in the evaluation:

- the baseline (Phase 2), to provide an overview of the base position of the FI in 2019/20 (i.e. when Challenge announced) and how this has changed through to 2020
- the process/interim evaluation (Phase 3) in 2022, to assess the nature and scale of changes in the sector since the baseline
- the impact evaluation (Phase 4) in 2024, to update contextual trends.

8.35 Table 8-4 sets out the secondary datasets and sources which will be analysed at UK level. It is worth noting that this table includes the secondary data presented in section 5 (Table 5-1)[36].

Table 8-4: Secondary datasets

Indicator	Dataset/ source	Time coverage	Sector detail
Gross value added (GVA) by sector	Annual Business Survey (ONS)	2008-2018	4-digit SIC
Turnover	Annual Business Survey (ONS)	2008-2018	4-digit SIC
Employment by sector	Annual Business Survey (ONS)	2008-2018	4-digit SIC
Employment by occupation	Working Future (Department for Education), BRES (ONS)	2017-2027 (Working Futures); 2008-2018 (BRES)	5-digit SIC
Gross operating surplus (GVA minus employment costs)	Annual Business Survey (ONS)	2008-2018	4-digit SIC
R&D expenditure by UK sector	BERD (ONS)	2010-2018	2-digit SIC
R&D expenditure by businesses (by sector)/GVA	BERD (ONS)	2010-2018	2-digit SIC
Total capital expenditure	Annual Business Survey (ONS)	2008-2018	4-digit SIC
Exports	Eurostat Comext	1990-2019	4-digit SIC
Share of exports in total turnover (%)	Eurostat Comext, UN Comtrade and ABS (ONS)	2012-2019	4-digit SIC

[35] This includes any gaps/limitations in the data that have already been identified that may limit any analysis.
[36] The 'Gateway to Research database' which records UKRI funding and collaborations was also considered as a source of evidence for the evaluation but UKRI cannot provide access to the database for the purpose of the evaluation.

Indicator	Dataset/ source	Time coverage	Sector detail
Export market share (UK as a share of global exports)	Eurostat Comext, UN Comtrade and ABS (ONS)	2012-2019	4-digit SIC
Imports	Eurostat Comext	1990-2019	4-digit SIC
Foreign Direct Investment	ONS	2016 - 2019	2-3-digit SIC
Patent applications (this will partially cover IP)	Patents by technology (OECD)	1999-2017	International Patent Classification
Energy consumption by industry	Energy use; by industry, source and fuel (ONS Environmental Accounts)	1990-2018	2-3 digit SIC
Emissions intensity (GHG emissions per real unit of GVA)	ONS Environmental Accounts	1990-2018	2-3 digit SIC
Gross operating surplus (GVA minus employment costs) (£)	Annual Business Survey (ONS) and output deflators from MDM-E3	2008-18	4-digit SIC
Incidence of skills shortages (vacancies) at sector level	Department for Education, Employer Skills Survey	2011-2019	2-digit SIC

Source: Cambridge Econometrics

Survey of companies across the FI

Purpose: To assess and track indicators at baseline and final evaluation stages. Data derived from the primary survey of companies in the FI will fill gaps in indicators that are not available from secondary sources, e.g. attitudes and behaviours in relation to R&D and innovation, skills and capabilities, and collaborations. The final evaluation survey will also ask further questions of beneficiaries of their experience and benefits from engagement in Challenge activities. This will inform an assessment of effects on engaged businesses, and on the plausible contribution by the Challenge to sector-level changes in attitudes and behaviours.

8.36 The focus of the sector survey will be on attitudes and behaviours towards innovation and environmental sustainability. It will cover indicators associated with, for example: innovation and R&D investment and activity; collaborative relationships within industry and with academics in FI; skills and capabilities; barriers and enablers to innovation and sustainability; factors influencing behaviours looking forward (to inform scenario analysis); awareness of Challenge activities. The surveys will be undertaken in two waves as described below.

8.37 **The first wave will be at baseline (Phase 2) in 2021** and will involve a CATI[37] survey of 400 companies across the FI (this should provide a suitable sample).[38] The survey will comprise mainly of closed questions (and last about 15 minutes). This will fill gaps in indicators not available from monitoring and secondary sources. It will gather data on the latest position (2021) and retrospectively for a view on the historic position at the time the Challenge was announced (2019).

8.38 **The second wave will be at impact evaluation (Phase 4) in 2023** and will involve a CATI survey of 400 companies, of which 300 companies will be from across the FI (15 minute interviews) and 100 companies with beneficiaries from across the TFI programme (30 minute interviews).[39] These will gather data on progress against key indicators/ asking questions in relation to the latest position (2023). It is worth noting that some companies may participate in both waves.

8.39 The beneficiary companies in the second wave will be questioned on specific activities undertaken as part of the TFI programme, the outcomes/ impacts experienced, the extent to which these may not have been achieved otherwise, and the difference the programme made in realising these benefits relative to other factors. The findings from survey will complement the more in-depth consultations as part of the bottom-up approach.

8.40 The survey work will be conducted by IFF Research. The sector survey sample will be stratified so that we achieve equal numbers of interviews across the six sectors. Within this, we will draw sample on a random basis to ensure a representative spread by size, region etc. For the beneficiaries, the sampling approach will be a simple attempted census, which should guarantee that the profile of achieved interviews reflects that of the population. The business database will be purchased from 'Market Location'.[40]

8.41 The survey questionnaires for the baseline and impact phases will be shared with UKRI for review and comment before finalising. The surveys will be piloted prior to full roll out.

8.42 The analysis of the survey data will involve the following key lines of enquiry: descriptive analysis of attitudes, behaviours and perceptions – to provide evidence on innovation, R&D, skills, collaborations within and across FI, environmental sustainability, key barriers etc.; analysis of changes in sector-level attitudes, behaviours and perceptions between both waves of the survey on key indicators; and analysis of the specific benefits of Challenge activities to surveyed beneficiaries.

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[37] Computer Assisted Telephone Interview.
[38] This would enable a confidence interval of +/-5 percentage points for a finding of 50% at the 95% level. Sub-group analysis could also be carried out for around 4 sub-groups (e.g. +/-10 percentage points for a finding of 50%).
[39] 15 minutes replicating the sector survey plus 15 minutes covering the impact of the programme.
[40] Market Location have coverage of over 97% of the UK's trading companies.

In-depth telephone interviews with wider stakeholders

Purpose: In-depth interviews will be undertaken with stakeholders to gather wider perspectives on the key issues, trends, barriers influencing competitiveness and environmental sustainability in FI. The interviews will inform the scenario analysis work, test the alternative/complementary explanations identified in the logic model, and try to understand the role of the TFI programme in contributing to outcomes/impacts.

8.43 At the baseline phase, we will undertake up to 30 stakeholder/ expert telephone interviews. These will help inform the scenario analysis (see below) and wider understanding of the FI. At the impact stage, we will undertake telephone interviews with 20 stakeholders. The topics to be covered include: state of innovation and skills in the FI; current and future trends influencing FI; testing issues from the scenario analysis (see later in this section) including key comparator countries in FI; perceptions on collaborations within and across FI and whether the FIs has more of a shared identity; other impact of the programme relative to other factors – wider systems influence (e.g. market, technological, economic, environmental); and the overall contribution and added value of the TFI programme. External stakeholders for interview will include those identified in the stakeholder map (see Annex E).

Modelling of economic and environmental change

Purpose: The economic modelling will provide a baseline reference case without intervention and take into account COVID-19 and Brexit. The historical baseline will be augmented with a forecast of GVA and employment for the FI sectors out to 2040. It is important to note that it would not be appropriate to make direct comparisons between outturns and the reference case. The economic modelling will also inform the scenario analysis. To be clear, the modelling of economic and environmental change will provide contextual evidence and not infer anything about the performance of the TFI programme itself.

Economic projections

8.44 We will develop projections for the six foundation industry sectors out to 2040 for GVA, employment and labour productivity. These projections will be derived from Cambridge Econometrics' in-house forecasting model, MDM.

8.45 MDM is maintained and developed by CE as a framework for generating detailed economic forecasts and analysing changes in economic structure. MDM provides a one-model approach in which the detailed industry and regional analysis is consistent with the macroeconomic analysis.

8.46 To analyse structure, MDM disaggregates industries, commodities, and household and government expenditures, as well as foreign trade and investment, and incorporates an input-

output framework to identify the interrelationships between industry sectors. The parameters of the behavioural relationships in MDM are estimated econometrically over time, within limits suggested by theory, rather than imposed from theory. The economy is represented as being in a continual state of dynamic adjustment, and the speed of adjustment to changes (in, for example, world conditions or UK policies) is based on empirical evidence.

8.47 In addition to the statistical mechanisms within MDM (which characterise economic relationships based on historical patterns), the model also methodically makes adjustments based on internal assumptions about the likely future. This is done by routinely assembling a team of economists to assess the latest available literature and evidence to revise the forecast's short-run outlook. It allows the model to account for major events such as Brexit or the COVID-19 outbreak, which is not well captured by the analysis of long-run historical trends.

8.48 To develop the projections for GVA and employment, we will apply the latest MDM sector forecasts (SIC 2-digit) for GVA and employment to the latest year of historical baseline data for each of the foundation industry sectors. The labour productivity projection will then be calculated from the GVA and employment projections.

8.49 The MDM model is updated once a year and the forecast is on track to be ready early March, subject to COVID disruption. We suggest using the March update as the basis of the projections as this update will incorporate the most recent economic developments.

Emissions projections

8.50 In addition to the economic projections, we will also develop greenhouse gas emissions projections for each of the foundation industry sectors. For the emissions projections we will use an off-model approach that applies evidence from the historical (and changing) relationship between economic performance and emissions together with the economic projections.

8.51 Emissions projections will be developed for each of the foundation industry sectors. The foundation industry sectors are defined using 4-digit level SIC codes whereas the ONS sectoral emissions data are defined at the 2-digit level. Adjustments will thus have to be made to the emissions data to estimate emissions for the foundation industry sectors before the projections are developed. This will be done by applying a simple rule about the relationship of emissions to an indicator for which 4-digit level data are available (for example, output).

8.52 Depending on the availability of data we will estimate the emissions in one of two ways. The first way is to use the historical relationship between GVA/employment and emissions together with projections. The second way is to first derive projections for energy consumption from the economic projections and then translate these into emissions using sector emissions factors. We will explore further which of these methods is the most appropriate.

International comparisons

Purpose: This will involve international comparison in terms of how the UK landscape and key intermediate indicators have changed in relation to selected comparator countries. The evidence here will not draw direct causal links between the Challenge and differences in performance, but will add contextual evidence to inform the Contribution Analysis (and not empirical counterfactual evidence).

8.53 We have selected Germany, France and Belgium as countries for comparison with the UK TFI sector baseline (phase 2) and at impact evaluation stage (phase 4). The international comparisons provide a yardstick with which we can measure the UK foundation industries' performance against key indicators. However, this task will provide contextual evidence and it would be inappropriate to interpret too much into the role of the Challenge in accounting for any differences in performance trajectory over the period under examination. The comparator countries were chosen based on the following criteria:

- UK domestic market penetration – a key objective of the TFI programme outlined in the business case is the displacement of imports into the UK domestic market.
- Importance of the UK market to the foreign exporter – countries that export a high proportion of their total exports to the UK are more likely to produce goods that are customised to the UK market (as opposed to countries exporting lower value-added goods across the world). These are the types of goods that UK producers are likely competing to sell on the domestic market.
- Data availability – to facilitate meaningful comparisons between countries, data should be comparable and consistent in terms of sector definitions and indicator definitions, and the methodology for collecting and collating the data.

8.54 To identify the most suitable comparator countries, we analysed the performance of both EU and non-EU countries across the above criteria. We found that Germany, France and Belgium performed particularly well. Table below summarises our findings for these three countries:

Table 8-5: Summary of UK domestic market penetration, importance of UK market, and data availability for Germany, France and Belgium

Country	UK domestic market penetration (importance of comparator country to UK supply)	Importance of UK market to foreign exporter	Data availability
Germany	Largest exporter to the UK in Manufacture of Paper and Pulp, and Manufacture of Chemicals and Chemical Products. Third largest foreign importer in Manufacture of Other Non-metallic Mineral Products, and Manufacture of Basic Metals.	Exports to the UK account for high share (5-7%) of total exports to the world in all the TFI sectors.	Very good – comparable data available from Eurostat

Country	UK domestic market penetration (importance of comparator country to UK supply)	Importance of UK market to foreign exporter	Data availability
France	Fifth largest exporter to the UK in Manufacture of Paper and Pulp and Manufacture of Other Non-metallic Mineral Products. Third largest importer in Manufacture of Chemicals and Chemical Products. Tenth largest importer in Manufacture of Basic Metals.	Exports to the UK account for high share (5-7%) of total exports to the world in all the TFI sectors.	Very good – comparable data available from Eurostat
Belgium	Seventh largest exporter to the UK in Manufacture of Paper and Pulp, and Manufacture of Basic Metals. Fourth largest exporter to the UK in Manufacture of Chemicals and Chemical Products. Ninth largest exporter to the UK in Manufacture of Other Non-metallic Mineral Products.	Exports to the UK account for high share (4-10%) of total exports to the world in all the TFI sectors.	Very good – comparable data available from Eurostat

Source: OECD (STAN database), Eurostat, and CE calculations.

Scenario analysis of 'plausible' futures

Purpose: Scenario analysis examines qualitatively plausible futures for the foundation industries and the role of R&D and innovation in these futures. It draws on existing evidence, stakeholder interviews, and economic projections. As well as informing the evaluation, the exercise will be useful to the UKRI programme team and the industries themselves. To build resilient plans, improving understanding is critical, both understanding of current forces and possible future forces. Developing scenarios is a known technique for achieving this.

What is scenario analysis?

8.55 Flexible long-term planning requires the ability to imagine the future. For the foundation industries, because investment decisions operate over long cycles and have far-reaching consequences for the potential viability of innovations, imagining the future in a way that has practical application is crucial.

8.56 Rather than trying to predict the future, scenario analysis aims to study multiple futures as systematically possible. In this approach, scenarios are imagined futures, not forecasts. More specifically, scenarios are internally consistent visions of the future with a plausible connection to the past. Scenarios describe the different kinds of futures that are possible, allowing decision-makers to consider how to prepare for them, what kind of ends are in fact sought, and how to move towards the most desired future.

8.57 Typically, scenarios are extreme versions of the future that can be used to develop plans and roadmaps. This extremity makes the scenarios especially useful for planning during periods of disruption or instability. If a plan or strategy can work well under each of the multiple

scenarios, then that strategy is considered to be more robust than others. This is sometimes referred to as a 'no-regret' strategy. Scenarios can be seen as tools for decision-makers to better understand the range of possible long-term changes and future options. Scenarios create a frame for discussions, strategies and direct operations. For the purpose of the evaluation framework, scenario analysis has been used to check the robustness of the proposed evaluation approach and methods in the context of a sector that is likely to be subject to significant disruption over the medium-term and has long-term investment cycles.

8.58 The scenarios will also be used to test the theory of change, in particular the alternative and complementary explanations, and to examine how the FI are evolving relative to the scenarios developed as part of the baseline. In doing so, this will strengthen the overall contribution analysis/ story.

Process

8.59 High quality scenario analysis requires desk research and stakeholder engagement to build plausible scenarios. There is a recognised process, which has been followed:

- Review of literature about current challenges of the sectors, views on possible changes to context (such as how policy might change as digitisation intensifies and widens), and possible futures (47 reports comprising 10 on general background, 11 cross sectoral reports and 26 sector specific reports)
- Interviews with sector experts (10)
- Workshops to build and refine scenarios (four internal workshops that developed seven scenarios, reduced to four, and confirmed in one workshop with the client group)
- Construction of a matrix to encourage discussions about similarities and differences between scenarios and frame the evaluation design and any related strategy building (the axes include reactivity and stress level).

The Scenarios

8.60 Four scenarios were developed to inform the evaluation framework, as shown in the table below.

Table 8-6: Scenarios of plausible futures for the Foundation Industries

Scenarios
Scenario One: Constant Flux
• No periods of stability because of constant external changes affecting the FI. Short periods of high demand and high throughput are rare and don't last. Downturns are often surprises rather than cyclical. Downturns can be long/short, sharp/soft and arise from multiple sources e.g. geopolitics, economic downturns, weather, competitor behaviour. • It becomes increasingly difficult to confidently predict future demand and to match traditional investment cycles.

- Material flow disruptions as well as extreme demand disruption are anticipated from causes such as dumping by international competitors, innovations flowing to China, and extreme challenges to investment cycles.

Scenario Two: Constrained technology flow

- 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.
- R&D within FI expected to shift to China, followed by customers leaving the UK, and government policy to shift to material security.

Scenario Three: Internally driven, flourishing

- UK government research and industry have solved the problems of material circularity. The FI move 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 supply of local recycled materials is expected to eventually under-cut imported virgin materials with the FI becoming the system that provides (re-cycles and renews) fundamental core molecules in service of the nation.

Scenario Four: Externally fed, flourishing

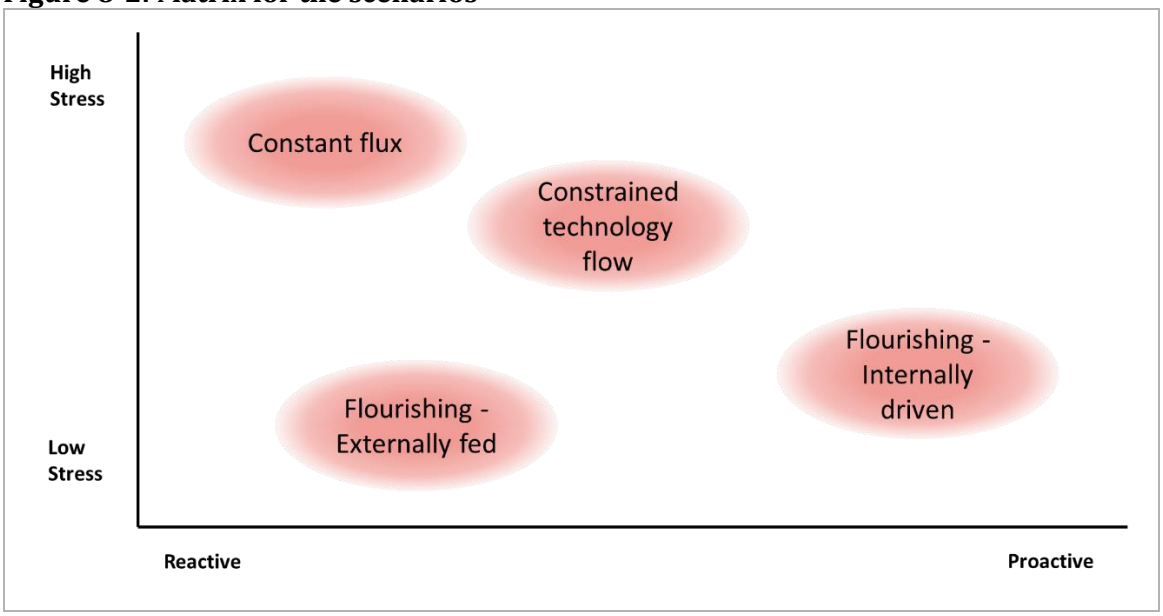
- UK government research and industry have solved the problems of carbon capture, utilisation and storage, and hydrogen production and distribution. Renewable electricity is cheaper than natural gas. The UK leads the world in low cost, low carbon foundation materials and easily finds export markets.
- A vigorous FI sector enthusiastically adopts technologies driven by other sectors and/or government policy (such as Carbon Capture Use & Storage, hydrogen distribution), and FI becomes the system that takes low carbon energy and imported molecules to deliver materials in service of the nation.

Source: IFM and SQW

8.61 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. However, the research indicated that business as usual is not in fact a plausible scenario. Indeed, the evidence suggests there is a significant gap between what the industry hopes will happen and what is likely to happen.

8.62 The scenarios can be placed on a matrix to encourage reflection on the implications of the scenarios. Below, the four scenarios are set against axes for stress and reactivity. This shows that scenario one, Constant Flux, is both reactive in terms of the sectors having to respond to rather than drive events, and high stress because of the instability. Scenario two, Constrained Technology Flow, is slightly less reactive and high stress. The two more positive scenarios, Externally fed - flourishing and Internally driven – flourishing, are both low stress positive futures but differ in terms of reactivity.

Figure 8-2: Matrix for the scenarios



Source: IFM and SQW

Key Insights

8.63 The scenario research captured many insights that are not directly featured in any of the scenarios. In some cases, this is because the insights were too detailed or specific, in others because they were too broad or universal. The full set is divided into critical, notable and other insights and presented in (Annex H:).

8.64 There is **one critical insight**, that there is a failure of many leaders in the FI to understand influences that will stop 'business as usual' continuing through the next decade. This is recognised within the business as usual scenario.

Applying the scenario analysis to the evaluation

8.65 The initial application of the scenarios to the evaluation is to consider whether the evaluation framework will still be robust under each scenario. Put another way, would the evaluation still provide evidence and insights relevant to the evaluation research questions if any of the scenarios came to pass. A simplified version of the assessment of the robustness of the evaluation framework against each scenario is presented below.

Table 8-7: Robustness of evaluation framework to scenarios

Scenario	Assessment of evaluation framework
Scenario One: Constant Flux	Strong – the selection of a theory-based approach that draws on multiple sources of evidence and considers the influence of external factors on change within the FI sub-sectors should be able to account for ongoing disruption better than purely quantitative or quasi-experimental approaches that focus strongly on numerical metrics. The contribution analysis should enable the construction of a story that explains the nature

Scenario	Assessment of evaluation framework
	of changes experienced and what has driven them, including the role of the TFI programme.
Scenario Two: Constrained technology flow	Strong – similar to scenario one, the selection of a theory-based approach should be able to identify the role of external factors in any progress on innovation within the FI.
Scenario Three: Internally driven, flourishing	Strong – the mixed methods approach will quantify changes to the sector and identify relative significance of routes to change. An important addition from this scenario is clarification of what 'flourishing' means. Traditional measures of increased turnover and GVA might not be appropriate. The framework has been refined to include a wider concept of 'flourishing', incorporating profitability, value of exports and market share of FI businesses in UK and international markets.
Scenario Four: Externally fed, flourishing	Strong – as for scenario three, the mixed methods approach will quantify changes to the sector and identify relative significance of routes to change. The useful insight from assessing the framework against this scenario is that the research should explore the implications for the sustainability of changes to FI if it is driven largely through external rather than internal changes. This will be important learning to share with the programme.

Source: SQW

8.66 In sum, the evaluation framework does operate effectively under each scenario. The theory-based approach selected is particularly useful in not merely measuring changes within a sector but identifying routes to change and the respective importance of different factors.

8.67 In subsequent phases of the evaluation the scenarios will also be used to test the theory of change, in particular the alternative and complementary explanations, and to examine how the FI are evolving relative to the scenarios developed as part of the baseline. In doing so, this will strengthen the overall contribution analysis/ story. Further detail on the scenario analysis is in Annex H:.

Impact analysis

8.68 We will analyse and triangulate all the evaluation evidence from the different research strands. The assessment will be made against the theory-based framework described in section 3 - testing the underlying logic and theory of change as to whether the ISCF programme delivered the intended outcomes and impacts. Specifically, we will follow the steps in Contribution Analysis outlined in section 3. In this, a plausible association can be made (or attribution is demonstrated beyond reasonable doubt) if the following are satisfied:

Plausible association in Contribution Analysis…

- A reasoned theory of change is set out
- The activities have been implemented as set out in the theory of change
- The chain of expected results, e.g. on direct beneficiaries and the wider sector can be shown to have occurred
- other influencing factors have been shown not to have made a difference, or the decisive difference.[41]

8.69 A key part of this will involve linking the bottom-up evidence from projects and workstreams to changes in contextual indicators and scenarios. For example, the bottom-up evidence will provide evidence on the extent to which FI companies benefiting have invested more in R&D. This could be benchmarked to average sector changes, and also considered in light of the progress against the scenarios that we have developed. We will hold a workshop to present and validate high level findings with the client and key programme stakeholders.

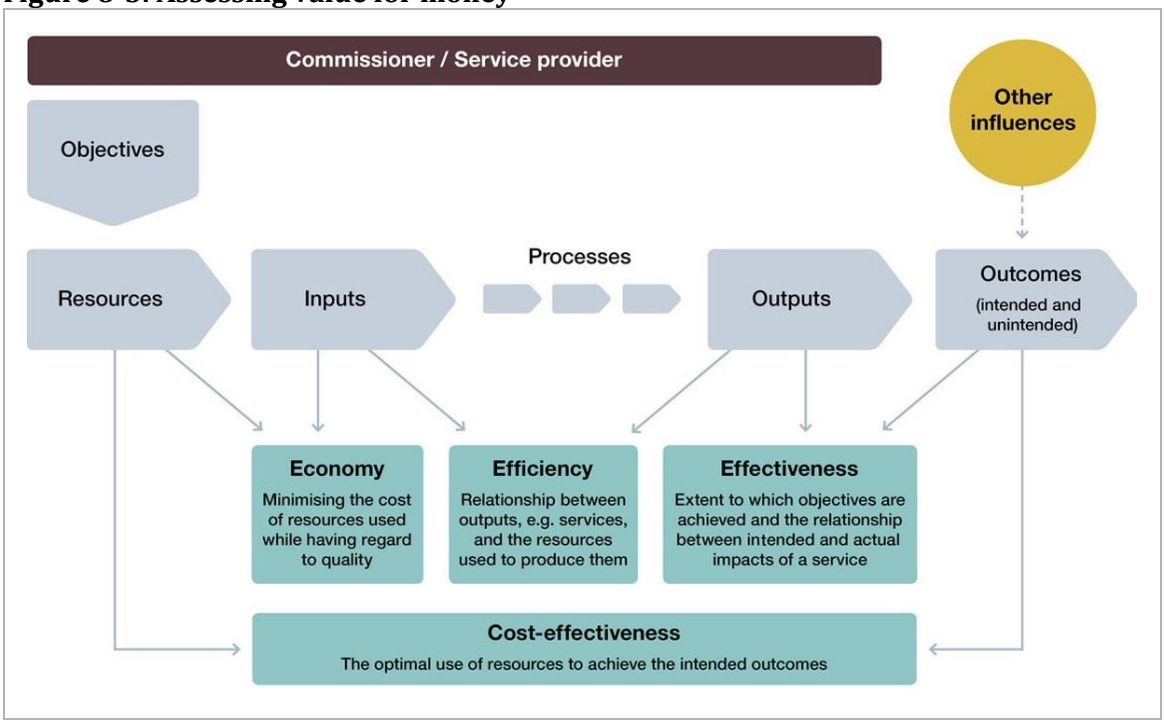
Approach to assessing value for money

8.70 An assessment of value for money (VfM)of public spending i.e. the optimal use of resources to achieve the intended outcomes requires consideration of the following (see Figure 8-3).

- **Economy:** minimising the cost in delivering the programme
- **Efficiency:** the relationship between inputs and outputs
- **Effectiveness:** the relationship between the intended and actual results of public spending (outcomes).

[41] These other influencing factors will be analysed from responses of businesses, academics, and other stakeholders (e.g. alternative explanations in the ToC). This will also involve question on: TFI programme had no influence; TFI contributed to outcomes, but was not necessary; TFI was an important contributory factor alongside others; TFI was the critical contributory factor

Figure 8-3: Assessing value for money[42]



Source: National Audit Office (undated); also referenced in Magenta Book (2020)

8.71 The evaluation will assess the economy, efficiency and effectiveness of the TFI programme (as part of the process and impact evaluations). However, it will not calculate a Net Present Value (NPV) and Benefit Cost Ratio (BCR). We do not think these will be appropriate or indeed meaningful given the objectives and activities of the TFI programme, the nature of the intended outcomes/impacts including the challenging timescales involved in realising (and quantifying) these benefits. As part of the contribution analysis, the priority will be to develop a more rounded assessment and evidence the extent to which the Challenge has achieved its objectives of improved competitiveness and environmental sustainability.

[42] nao.org.uk. (undated). Assessing Value for Money. [online] Available at: https://www.nao.org.uk/successfulcommissioning/general-principles/value-for-money/assessing-value-for-money/#

9. Evaluation plan

9.1 This section sets out the evaluation plan, in terms of which methods will be employed at each phase of the evaluation and the timetable for each phase.

Evaluation phasing

9.2 The three phases of the evaluation – baseline, process and impact (excluding scoping and the developing of the evaluation framework) – are shown below, along with the respective evaluation methods that will be deployed in each phase.

Figure 9-1: Evaluation phases and methods

	Evaluation Phase:	Baseline	Process	Impact
Top down methods	Analysis of sector indicators from secondary data	✓	✓	✓
	CATI survey with companies across the FI	✓		✓
	Modelling of economic and environmental change	✓		✓
	International comparison	✓		✓
	Scenario analysis of 'plausible' futures	✓	✓	✓
	In-depth telephone interviews with wider stakeholders	✓	✓	✓
	Case studies (process and impact)		✓	✓
	Workshops	✓	✓	✓
Bottom up methods	Analysis of applicant and monitoring data	✓	✓	✓
	In-depth telephone interviews with TFI delivery team	✓	✓	✓
	In-depth telephone interviews with companies*		✓	✓
	In-depth telephone interviews with glass facility & users*		✓	✓
	In-depth telephone interviews with academic researchers*		✓	✓
	In-depth telephone interviews with investors*		✓	✓

Source: SQW

** Interviews will be with successful and unsuccessful applicants / beneficiaries and non-beneficiaries*

Phase timetables

9.3 The following timetables set out in more detail how each phase will be delivered. Note, the timetables for the process and impact phases are indicative and will be confirmed at the start of each phase. Technology assessment is not currently included, pending discussion with the client group.

Figure 9-2: Timetable for baseline phase

	Oct-20	Nov-20	Dec-20	Jan-21	Feb-21	Mar-21	Apr-21	May-21
Baseline phase								
Internal team briefing	▲							
Analysis of sector indicators from secondary data	■	■			■	■		
CATI survey with companies across the FI					■	■		
Modelling of economic and environmental change					■	■		
International comparison						■		
Scenario development of 'plausible' futures	■	■	■	■				
In-depth telephone interviews with wider stakeholders		■	■					
Workshops				▲		▲	■	■
Baseline report					■	■	◆	■
Client meeting on report						■	▲	■

Meetings: ▲
Milestones: ◆

Figure 9-3: Timetable for process (and progress) phase

	Jan-22	Feb-22	Mar-22	Apr-22	May-22	Jun-22	Jul-22	Aug-22	Sep-22	Oct-22
Process evaluation phase (including progress)										
Design detailed research tools	■									
Analysis of applicant and monitoring data	■	■								
Analysis of sector indicators from secondary data (update)		■	■							
Interviews: delivery team, companies, glass facility & users, researchers, investors, stakeholders				■	■					
Analysis of interview evidence						■				
Workshops x2							▲ ▲			
Process and progress evaluation reports								■	◆ ◆	■
Client meetings x4	▲			▲			▲			▲

Figure 9-4: Timetable for impact phase

	Jan-23	Feb-23	Mar-23	Apr-23	May-23	Jun-23	Jul-23	Aug-23	Sep-23	Oct-23	Nov-23	Dec-23	Jan-24	Feb-24	Mar-24
Phase 4: Final phase															
Revise research tools	■														
Analysis of applicant and monitoring data		■							■						
Analysis of sector indicators from secondary data			■												
Modelling of economic and environmental change				■											
International comparison					■										
CATI survey with companies across the FI							■	■							
Interviews: delivery team, companies, glass facility & users, researchers, investors, stakeholders					■	■	■	■							
Analysis of interview evidence									■						
Analysis of survey data									■						
Impact analysis										■	■	■			
Workshop													▲		
Draft and Final reports (including 8 case study write-ups)													■	◆ ◆	■
Client meetings x4	▲				▲					▲					▲
Summary report and presentation															■
Project management for all 4 phases (2020-2024)															

Source: SQW

Risk register

9.4 Table 9-1 below sets out an updated risk register for the study, specifying the likelihood, potential impact, and mitigating actions for each identified risk. This includes risks that are pertinent across the whole evaluation, as well as those that are relevant only to specific elements. Throughout the study, this risk register will be treated as a live document, which will be monitored and reported on as part of the regular client updates.

Table 9-1: Risk register

No.	Risk	Likelihood	Impact	Owner	Mitigating actions
Wider context					
1	Economic and political change, particularly due to impacts of Covid-19 and Brexit make it difficult to assess outcomes/impacts and/or attribute impact to TFI specifically	High	Medium	SQW & UKRI	• Checkpoints in project plan to reflect on and adapt the approach • Contribution analysis considers the relative role of TFI vs other factors that could also explain observed outcomes, drawing on full range of mixed methods, including primary research; focus on 'plausible' contribution of TFI
Programme delivery					
2	Timing of evaluation (to be completed within the programme period) limits the ability to evidence outcomes/impacts	Medium	High	SQW	• Explicit recognition from the outset on challenges associated with evidencing indirect effects • Theory-based approach using different sources of evidence to mitigate the effect of insufficient data from one source
3	Substantive changes to the focus, approach or timeframes of TFI (utilising flexibility of ISCF model) require substantive change in process and/or impact evaluation approach	Medium	High	UKRI & SQW	• Close working with the TFI team throughout to ensure SQW is sighted on any significant changes to the delivery of the programme. In response, SQW will seek to adapt the evaluation when required. • Checkpoints in project plan to reflect on and adapt the approach • Evaluation scope agreed between UKRI and SQW
Fieldwork					
4	Low participation in fieldwork at different stages of the study	Medium	High	UKRI & SQW	• We will ask relevant client-side or partner organisations to assist in 'warming up' contacts and highlighting the importance of the study • We will be flexible on when interviews can take place, including before and after work hours; and we will be clear on expectations of participation and on data confidentiality to give reassurances

No.	Risk	Likelihood	Impact	Owner	Mitigating actions
					• Mixed methods will help to minimise the impact of low participation, e.g. using secondary datasets for longer-term effects when survey attrition is an issue. A typical response rate would be 30-35%.
Data and analysis					
5	Gaps, deficiencies or delays associated with programme monitoring data expected to be gathered from TFI team	Medium	High	UKRI	• SQW will work with UKRI to understand the type of data that is/will be collected and when • SQW will provide templates where useful to help fill gaps in monitoring data, and/or use baseline research • Programme monitoring data will be complemented with data from other sources to cover any gaps, if possible
6	Low numbers of participants and unsuccessful applicants reduces value of econometric analysis	Medium	Medium	UKRI & SQW	• UKRI will aim to maximise participation in the Challenge at all stages • The mixed methods, theory-based evaluation approach means that the final evaluation judgement is not overly dependent on the econometric analysis. The inclusion of econometric analysis would strengthen the assessment of impact but is not critical.
External communications & dissemination					
7	Expectations of audiences for the evaluation misaligned with nature of evidence	Medium	Medium	UKRI & SQW	• It is important to manage the messaging from study outputs with different audiences. SQW will work closely with the client group to communicate to key audiences the type of evidence that will be available and when, especially at the evaluation framework stage and at regular reporting intervals. • SQW will present evidence transparently with any caveats and limitations clearly articulated. • UKRI will also be responsible for updating/communicating with relevant stakeholders at regular intervals
8	Findings from the evaluation are not fully understood and/or acted upon by all audience groups	Medium	Low	UKRI & SQW	• UKRI to help SQW identify key audiences, understand how they differ, and any sensitivities that may be associated with them • SQW will tailor communications to specific audiences to ensure all groups are clear on the methods, findings and implications.

No.	Risk	Likelihood	Impact	Owner	Mitigating actions
Project management & practicalities					
9	A large project team is not well-managed/ well-briefed	Low	Medium	SQW	• We have well established project management procedures in place to ensure the project team is well-managed and well-briefed. This includes e.g. holding regular internal briefings so that team members are clear on what is expected, and how the wider study is progressing.
10	Unexpected unavailability or capacity of SQW team members to complete the work	Low	High	SQW	• Once work is won, it is booked on our commitment booking system, so it cannot be displaced. In the event of absence (potentially heightened because of the pandemic), we will replace team members with staff of equivalent standing, agreed with UKRI. • To minimise impact, handover sessions will be held to ensure smooth transition. As per below, project files are stored centrally, which minimises any loss of knowledge.
11	Data security issues or breaches	Low	Medium	SQW	• All data and information for the project will be managed to comply with SQW's Information Security Policy, which has been updated following GDPR. The assigned Project Director has overall responsibility for ensuring the project's compliance with SQW's Policy.
12	IT failure	Low	High	SQW	• Project files are securely stored on SQW's central servers, which are backed up daily, in accordance with SQW's Information Security Policy. SQW's ICT defences are certified as complying with the requirements of the Cyber Essentials scheme.

Source: SQW

Annex A: List of consultees

A.1 As part of the scoping phase, twenty-two consultations were undertaken with key individuals from UKRI and other sector experts/stakeholders. The aim of the consultations was to explore key elements of the programme including the businesses within scope, the logic of the programme's intervention, and the evaluation priorities. Consultations for the scenario analysis explored what might affect the innovation behaviour of and prospects for the FI.

Figure A-1: Consultees

Name	Role
Bruce Adderley (x2)	Challenge Director - Transforming Foundation Industries
Ben Walsh (x2)	Deputy Challenge Director – Transforming Foundation Industries
Sarah Connolly (x2)	Innovation Technologist - Transforming Foundation Industries
Hugh Falkner	Innovation Lead - Transforming Foundation Industries
Zoe Price	Programme Manager - Transforming Foundation Industries
Paul Lampard	Project Manager - Transforming Foundation Industries
Stuart Russon	Impact and Performance Manager - Transforming Foundation Industries
Rosanna Greenop	Senior Portfolio Manager – UKRI EPSRC
Bruce Colley	UKRI Investor Partnership team
John Topliss	Head of Property and Capital Portfolio, ISCF Governance
Ajay Kapadia	Knowledge Transfer Manager – KTN
Jose Argudo	Evaluation, Lead Specialist – Innovate UK
Cathryn Hickey	CEO – Applied Materials Research, Innovation, Commercialisation Company (AMRICC)
Chris McDonald	CEO – Materials Processing Institute
David Brown	CEO (ex) – Chemical Engineers
Graham Hillier	CTO (ex) – Centre for Process Innovation
Iain Walpole	Head of Environmental Sustainability – Hanson UK
Mikael Hannus	VP Group R&D and Innovation – Stora Enso Executive Secretary – Wallenberg Foundation
Richard Leese	Director – MPA Cement Director for Industrial Policy, Energy and Climate Change – Mineral Products Association

Source: SQW and IFM

Annex B: SIC codes for Foundation Industries

B.1 As there is no agreed definition of foundation industries, the TFI challenge team provided a working definition based on 2007 SIC codes, shown below. It was noted that this definition is relatively narrow, focusing predominantly on the primary producers.

Table B-1: SIC codes for Foundation Industries

SIC Code	Description
Paper and pulp	
17110	Manufacture of pulp
17120	Manufacture of paper and paperboard
17211	Manufacture of corrugated paper and paperboard, sacks and bags
17219	Manufacture of other paper and paperboard containers
17220	Manufacture of household and sanitary goods and of toilet requisites
17230	Manufacture of paper stationery
17240	Manufacture of wallpaper
17290	Manufacture of other articles of paper and paperboard n.e.c.
Chemicals	
20110	Manufacture of industrial gases
20130	Manufacture of other inorganic basic chemicals
20140	Manufacture of other organic basic chemicals
20150	Manufacture of fertilizers and nitrogen compounds
20160	Primary plastics
20590	Manufacture of other chemical products n.e.c.
Glass	
23110	Manufacture of flat glass
23120	Shaping and processing of flat glass
23130	Manufacture of hollow glass
23140	Manufacture of glass fibres
Ceramics	
23310	Manufacture of ceramic tiles and flags
23320	Manufacture of bricks, tiles and construction products, in baked clay
23410	Manufacture of ceramic household and ornamental articles
23420	Manufacture of ceramic sanitary fixtures
23430	Manufacture of ceramic insulators and insulating fittings
23440	Manufacture of other technical ceramic products
23490	Manufacture of other ceramic products n.e.c.

SIC Code	Description
Cement	
23510	Manufacture of cement
23520	Manufacture of lime and plaster
23630	Manufacture of ready-mixed concrete
23640	Manufacture of mortars
23650	Manufacture of fibre cement
Metals	
24100	Manufacture of basic iron and steel and of ferro-alloys
24410	Precious metals production
24420	Aluminium production
24430	Lead, zinc and tin production
24440	Copper production
24450	Other non-ferrous metal production

Source: Transforming Foundation Industries Challenge Team

Annex C: Challenge activities, monitoring and governance

Programme activities

C.1 There are five distinct workstreams of activities within the TFI Challenge, summarised below in Table C-. Workstreams 1 and 2 aim to accelerate growth in the foundation industries and Workstreams 3, 4 and 5 aim to transfer knowledge and scale new technologies. The table outlines key activities for each workstream, and the value of funding allocated.

Table C-1: TFI programme activities

#	Workstream and value of ISCF grant funding	Key activities
1	**Establishment of the foundation industries pilot scale facility (£15m)**	**Construction of a pilot facility** (incl. equipment) for the glass sector in St. Helens • Direct Award Grant, with competition run in March 2020 • Project duration approximately 30 months from September 2020 to run Summer 2022 • Development of a pipeline of projects for the facility (Note, to be delivered by Glass Futures not UKRI.) • Development of a tiered membership scheme for the facility (Note, to be delivered by Glass Futures not UKRI.)
2	**CR&D and phased demonstrators to support industry (£31m)**	Series of six industry-led CR&D competitions • **Fast Start (£3m)** - competition run from October 2019 to February 2020. Project duration c.3-12 months, with projects starting from September to December 2020 • **TFI Building a resilient recovery (£8m)** – competition run from August to November 2020. Project duration 12 months, with projects running from April 2021 to April 2022 • **TFI CR&D (£8m)** – competition run from January to March 2021. Project duration c.12-24 months, with projects starting from August 2021 • **TFI Small CR&D (£1.5m)** – competition to run from June to September 2021. Project duration c.3-12 months, with projects starting from February 2022 • **TFI Demo (£13.5m)** - competition to run from December 2021 to March 2022. Project duration 24 months, with projects starting from August 2022 to August 2024 • **Future ready (TBC)** - competition run from September to December 2022 (TBC). Project

#	Workstream and value of ISCF grant funding	Key activities
		duration up to 18 months, with projects starting from May 2023
3	**New approaches to sustainable foundation industries – connecting universities and firms (£5m)**	Competition organised to facilitate knowledge transfer from academics to companies, with companies providing matched funding for projects • **ISCF Transforming Foundation Industries Research and Innovation Hub Call**, with competition run from July to December 2020 and Hub awarded funding in January 2021 • Project duration 36 months, to start in April 2021 and end in March 2024
4	**Establishing the foundation industries as a sector (£5m)**	**Developing a sector strategy** • Part of **Network+** ➢ coordination and development of a network across the foundation industries ➢ competition for small projects ➢ research papers produced • **ESRC activity** – duration five months from March to August 2020 • **Skills** (TFI sector skills report; training and skills development) - duration four months from March to June 2020 • **Resource efficiency mapping** (Innovate UK led) - duration four months from March to June 2020 • **UKSBS/Competitions (TBC)** – project start date Sep/Oct 2020 to run to February 2024
5	**Late stage finance (£10m)**	Private Equity/Investor Partnership programme (duration 12-24 months, with project start date TBC and end date March 2024) • **Phase 1 - Investor Partnership Competition** – competition run from October to December 2020, with selection interviews held in January 2021 • **Phase 2 – Investor Partnership SME Competition** – R&D competitions to be run every six weeks from April 2021 to March 2022. Investors to identify SMEs to participate apply, with TFI also able to identify SMEs to apply if required.

Source: UKRI

Programme monitoring

Planned monitoring data collection

C.2 Table C-2 outlines the planned monitoring data collection to be completed for each workstream as part of the programme.

Table C-2: Planned monitoring data collection

Source	Lead	Frequency	Summary
Competition application forms	TFI Team (workstreams 2, 3, 4), Investor Partnership (workstream 5)	Once at project start	Successful and unsuccessful application forms for each competition. Information collected includes project rationale, approach, team members and target market; expected project outputs and impacts; project costings, risks.
Funders Panel sheet	TFI Team (workstreams 2, 3, 4), Investor Partnership (workstream 5)	Once at application stage	Information includes assessor's score, project costs, team details, research category and innovation area for both successful and unsuccessful projects.
Monitoring Officer - Close out reports	UKRI Monitoring Officers	Once at project close	Reflection on key project activities, including spend to profile and activities completed compared to planned. This also includes due diligence checks and feeds into an Innovate UK database held at Innovate UK.
Benefits Realisation Plan	TFI Team	Dependent on project length	Details benefits and their related objectives, benefits, outcomes, capabilities outputs and inputs. Also lists units of measure and sources, current RAG/forecast for each benefit and benefit risks. There are ten benefits in the Realisation Plan. Coverage of these vary according to each workstream: • Deliver commercially viable technologies • Reduce technology adoption risk • Increased skilled and more diverse FI workforce • Delivery of an R&D scale up facility focused on glass • Increase in FDI • Sector Identity developed • Increased PE investment • More PE companies investing in the UK • Closer collaborations across the Foundation Industries • Increased Academic/industry collaborations
Glass Futures Key Performance Indicators (KPIs)	TFI Team (for workstream 1)	Quarterly	Progress against a list of 22 KPIs across themes including: • Activities (incl. engagement, delivery and marketing) • Outputs (incl. partner numbers, investment, project numbers)

Source	Lead	Frequency	Summary
			• Impact measures (incl. ED&I; job and apprenticeship numbers; income, revenue and GVA; and additional co-investment, investment and funding).
Hub Key Performance Indicators (KPIs)	TFI Team (for workstream 3)	Quarterly	To be designed by the TFI Team (Stuart and Rosanna) in collaboration with the successful applicants.
Network+ Key Performance Indicators (KPIs)	TFI Team (for workstream 4)	Quarterly	Progress against a list of eight KPIs across four key themes: engagement and networking; community leadership; commissioning of small grants; equality, diversity and inclusion.

Source: SQW

Participant numbers to date and anticipated

C.3 The table below sets out participant numbers to date and anticipated based on information available from UKRI. Current implementation progress means there is uncertainty regarding likely applicants to different calls and participants in different activities. As more information becomes available, we will update the table.

Table C-3: Competition and applicant data (to date)

	Number of successful applicants	Number of unsuccessful applicants	Notes
Workstream 1			
Pilot Facility competition	1	-	-
Workstream 2			
CR&D Fast Start	12	9	Originally 13 successful applicants but one has withdrawn.
Resilient Recovery	21	50	
TFI CR&D	-	-	Competition not yet run.
TFI Small CR&D	-	-	Competition not yet run.
TFI Demo	-	-	Competition not yet run.
Future ready (TBC)	-	-	Competition to be confirmed and not yet run.
Workstream 3			
Hub	1	To be confirmed	Two stage competition (outline and full proposal)
Workstream 4			

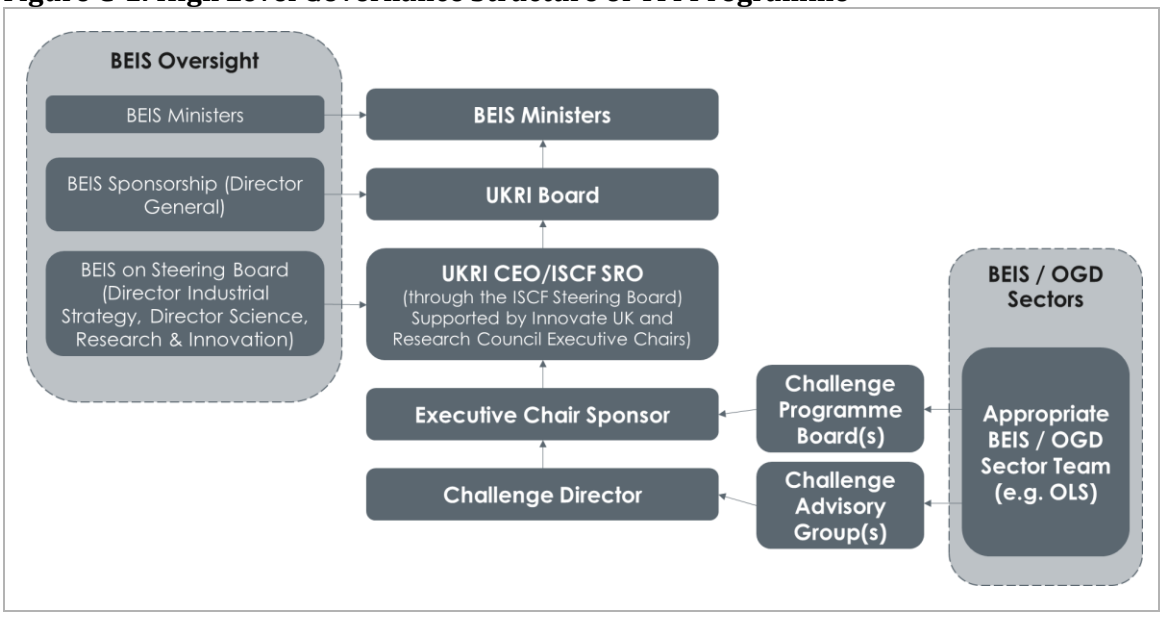
	Number of successful applicants	Number of unsuccessful applicants	Notes
Network+	1	3	
UKSBS/Competitions (TBC)	-	-	Competition not yet run.
Workstream 5			
Investor Partnership Competition	4 (estimated)	3 (estimated)	
Investor Partnership SME Competition	10 (estimated)	12 (estimated)	Estimate an 80% success rate.

Source: SQW

Management and governance arrangements

C.4 Figure C-1 depicts the high-level governance structure for the TFI programme. BEIS is responsible for overall governance of all ISCF programmes, including TFI. 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.

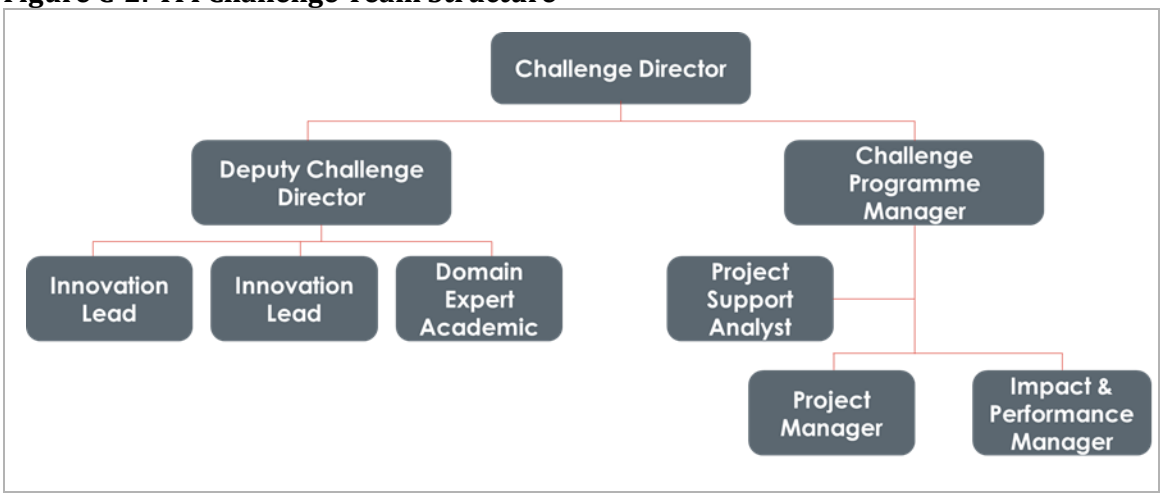
Figure C-1: High Level Governance Structure of TFI Programme



Source: SQW adapted from UKRI TFI Delivery Plan

C.5 Figure C-2 outlines the TFI Challenge Team Structure. The TFI programme is delivered by a core programme delivery team and is supported by wider UKRI support functions, as required (for example, legal and compliance; communications; ISCF evaluation lead).

Figure C-2: TFI Challenge Team Structure



Source: SQW adapted from UKRI TFI Delivery Plan

Annex D: Detailed logic model and theories of change for TFI workstreams

Logic model and theory of change

D.1 It is considered good practice and recommended in government guidance on policy evaluation,[43] to develop a logic model and theory of change that explicitly articulates the context and rationale for a policy or programme, and describes the relationship between the inputs, activities, outputs, outcomes and impacts. This instructive tool helps to structure an evaluation and inform the collection of evidence that would test whether the underlying logic and theory has happened in practice. Using the tool helps evaluators to test the extent to which, and how, the outputs, outcomes and impacts have been achieved and the causal links between these and the activities (i.e. the theory of change). In short, the approach provides the basis for developing a coherent monitoring and evaluation framework in two ways:

- informing the identification of indicators for monitoring and assessing performance
- outlining the main features of an intervention and in doing so framing the key research questions for the evaluation.

D.2 Taking account of the above, this section sets out a refined logic model and theory of change for the TFI programme. This has been developed by drawing on the original 'Benefits Map'[44] that was set out by UKRI and is also informed by our scoping discussions and document review.45 We wish to highlight that in refining the logic model, the programme documentation that we have drawn on was not always consistent. In addition, we have not fully captured all the detail of the programme as it is not possible to capture every single route to impact.

D.3 The scoping discussions provided mixed views on whether the UKRI's intervention logic was appropriate. Overall, the logic model was considered relevant and according to one consultee, *"still stands in terms of what we're hoping to achieve"*. The UKRI's Benefits Map reflects that TFI is a complicated programme – and presentationally consultees thought that the map was difficult to navigate. Moreover, there are elements that were recognised as being missing, including a clear theory of change, and the changes required in the sector in terms of attitudes and approaches to innovation. Reflecting on this, it will be important for the evaluation framework to present a way of prioritising the key measures and key routes to impacts.

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[43] HM Treasury (2020) *Magenta Book: Central Government guidance on evaluation*. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/879438/HMT_Magenta_Book.pdf

[44] UKRI (20 April 2020) *Benefit Map – Transforming Foundation Industries Challenge – Wave 3 ISCF. Issue: 0.9 DRAFT*

UKRI, (30 April 2019) *ISCF Transforming Foundation Industries Business Case*

Further, the ToC may evolve as the programme develops, meaning it may be sensible to revisit the ToC at the interim report.

D.4 Informed by the scoping discussions and review of documents, the remainder of this section sets out the *Strategy* (context and rationale), *Delivery* (inputs and activities) and *Benefits* (outputs, outcomes and impacts) of the programme. This is supported by theories of change for each of the five workstreams of the programme as presented in Annex C.

Strategic context and rationale

D.5 The Foundation Industries (FI) – 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.46 Collectively, FI are valued at £53.5bn and employ c. 200k people – mainly outside of the south-east, and often in areas of economic deprivation (e.g. Grangemouth, Teesside, east coast of Yorkshire, Merseyside, the Midlands). FI are capital intensive and are associated with high consumption of raw materials and energy in production. The Government's commitment to move to a 'net zero' economy means that the UK's FI must accelerate the pace at which they reduce their emissions. It also underlines the importance of cost-effective policy interventions to maximise opportunities for economic growth as the UK transitions to a green economy, whilst not putting businesses at a competitive disadvantage. This is pertinent in the context of cost competition from abroad due to larger scale-lower cost production and greater support for innovation. There is an opportunity for a disparate group of six sectors to work collaboratively to address the following common challenges to remain internationally competitive and become more 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 currently in place stifle innovation (e.g. traditional technologies and systems are preferred, preventing the benefits of data-driven processes) while 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:** private investors lack understanding of innovation and technologies developed and used by firms within FI, limiting access to private finance. 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.

[46] Knowledge Transfer Network (2019) Transforming Foundation Industries: ISCF Challenge Workshop on Cross-sector Priorities

- **Negative externalities:** FI are the largest industrial polluters, accounting for around 10% of the UK's total carbon emissions. This wider environmental cost may not be fully taken into account by producers, potentially limiting the incentive to modify/ invest in their processes.
- **Positive externalities (spillover benefits):** technology advancements within (and across) FI and other sectors (e.g. manufacturing, construction) lead to positive externalities through 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.

D.6 Given the above, 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 and contributes to the Government's net zero target. The focus of the TFI ISCF will be on 'resource and energy efficiency'.

Objectives

D.7 According to the Business Case, the overarching aim of the programme is as follows:47

By 2024, transform the UK's Foundation Industries so that they are internationally competitive in manufacturing products vital for the economy in an environmentally sustainable way.

D.8 This is underpinned by five key programme objectives, relating to Table D-1: 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.

D.9 The scoping discussions indicated that while all the objectives were considered important, there was some uncertainty over which ones should be prioritised (and how) to ensure programme outcomes and impacts are maximised, and address the original rationale for the intervention (i.e. the common challenges described above).

D.10 The objectives are likely to be addressed over different timescales during and beyond the evaluation period (2020-24). This reflects the nature of the long investment cycles as associated with FI, as indicated above, and the length of time it takes for innovations to occur.

D.11 Table D-1 below sets out the five high-level objectives, and aligned to these, the specific measurable objectives.

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

Table D-1: TFI programme – Objectives

#	High-level objectives	Specific measurable objectives
1	**Accelerate innovation and new collaborations** across the sectors via delivery of Pilot Scale facilities and CR&D	• To have delivered commercially viable technologies that aim to achieve a 5% reduction in either energy or resource use in an environmentally sustainable manner (at the system level). These will include energy optimisation technologies, process optimisation, waste and recycling and new product and service development within the sectors of cement, glass, metals, paper, chemical and ceramics. • Reduce technical/economic risk of adopting/developing resource/energy efficient technologies within foundation industries. Evidenced by an increase in technology-related investment by a target of at least 5% by the companies involved in the programme
2	**Increase multi/inter-disciplinary research and innovation** across the sectors through supporting development of the foundation industries as a sector	• To contribute to reducing or de-risking common technological and socio-political barriers (e.g. understanding of the value of the foundation industries at the personal, regional and national level) in the foundation industries, to enable the sectors to meet long term sustainability goals. • To have doubled the volume of collaborative publications, bid submissions, and commercial partnerships in foundation industries via an increase in industry-academia research engagement.
3	**Develop closer academic and industry links** through programmes dedicated to technology transfer	• To increase collaboration, evidenced through publication of research papers (10 Published) and patents (3 drafted), between academics and industry to solve common environmental sustainability issues - increasing the academic standing of foundation industry groups in the UK and transferring research-based technology into the sectors of cement, glass, metals, paper, chemicals and ceramics.
4	**Accelerate growth of new technology and fast-growing businesses** across the value chain through co-investment with Private Equity	• To co-fund, leveraging the TFI investment with four-fold match by Private Equity, start up and fast growth companies with environmentally sustainable technologies specific to the foundation industries (including its supply chain and technology providers). • By 2024, increase by 50% the number of private equity investors and investment in the foundation industries (including its supply chain and technology providers).
5	**Increase FDI in the UK and business investment in R&D** via CR&D and pilot scale facilities	• To deliver an R&D scale up facility focused on glass manufacture, to be operational by 2022. Engage with established national and international organisations involved in the glass sector supply chain to mitigate future reliance on UK government funding. • To increase technology-focused skills and capabilities within the foundation industries through cross-sector courses, industry-academia secondments, and increased technology training within apprenticeships.

Source: UKRI

Inputs and activities

D.12 The key programme inputs include ISCF grant funding (£66m) and industry matched funding (£83m). There is further in-kind time, resource, expertise/knowledge from the ISCF team, industry and academia. The standard core programme delivery team is supported by wider UKRI support functions, as required.48 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 will be reviewed at regular intervals.

D.13 The programme is organised into five workstreams of activities as shown in Table D-2. These aim to accelerate growth in the foundation industries (workstream 1 and 2), and transfer knowledge and scale new technologies (workstreams 3-5).

Table D-2: TFI programme – Activities

#	Workstream and ISCF grant funding	Key activities
1	Establishment of the foundation industries pilot scale facility (£15m)	• Construction of a pilot facility (incl. equipment) for the glass sector in St. Helens
2	CR&D and phased demonstrators to support industry (£31m)	• Series of industry led CR&D competitions
3	New approaches to sustainable foundation industries – connecting universities and firms (£5m)	• Competition organised to facilitate knowledge transfer from academics to companies, with companies providing matched funding for projects
4	Establishing the foundation industries as a sector (£5m)	• Sector strategy • Part of Network+ • coordination and development of a network across the foundation industries • competition for small projects • research papers produced • ESRC activity • Skills (TFI sector skills report; training and skills development)
5	Late stage finance (£10m)	• Selection of investors • Funding competition for companies

Source: UKRI

D.14 In addition, there are programme level activities such as central marketing activity; monitoring data collection; and governance activities as indicated above.

[48] For example, legal and compliance; communication support; ISCF evaluation lead; operations

Benefits

D.15 Following from the activities are the **outputs** i.e. the short-term effects expected from the programme that can normally be observed, counted and therefore monitored. They are generally in the direct control of the delivery organisation and indicate progress, highlighting areas of over and underperformance. Table D-3 sets out the outputs over time[49] for the TFI programme for the five workstreams. For example, under the second workstream the CR&D competitions are expected to attract applications from organisations in the foundation industries, awards made, partnerships developed between organisations, feasibility/ CR&D / demonstrator projects progressed (2022-23), and eventually completed by the end of the programme (2024).

D.16 The outputs are expected to translate into **outcomes and impacts**, which are presented in Table D-4. The outcomes reflect the overall aims of the programme and the changes it is expected to bring about. This includes both medium-term and longer-term outcomes. They can be defined as the subsequent effects on behaviour, capacity and/or performance of the businesses, research communities, and other organisations/ individuals. For example, late stage financing activities (workstream 5) attracts additional investment from private equity for companies with clean-tech innovations. Impacts are the final effects that address the original rationale for the programme. In the above finance example, the final impacts would be reduced barriers to investment, improved competitiveness and improved business performance/ growth (e.g. in terms of jobs and turnover). The outcomes and impacts of the programme presented below broadly can be considered to relate to the following areas: *economic, innovation, skills and environmental.* We have also highlighted impacts that we think are more likely to be measured post-evaluation (i.e. after 2024).

D.17 The programme will need to ensure that, and the evaluation will need to assess whether, delivery and eventual outcomes/impacts amount to 'more than the sum of the five parts' of the Challenge. For example:

- Does delivery enable scaling-up of activities?
- Can activities be replicated beyond the programme?
- Are there any mechanisms for shared learning and knowledge across and within workstreams?

9.5 The last of these is important for improving delivery and performance of the programme

[49] Indicative timescales for benefits aspects of the logic model are included within the logic model to provide an indication as to when effects may occur.

Table D-3: TFI programme – Outputs

Benefits

Outputs

Workstream 1:
- Collaboration with 5 glass sector and supply chain organisations to deliver a £37m glass pilot scale facility
- At least one international company within the glass supply chain involved in the delivery of the facility
- £22m match funding pledged

Workstream 2:
- CR&D competition (c.£8m) and a small-scale feasibility study (c.£5m) delivered
- Match funding requirements met on CR&D competition (c.£8m) and a small-scale feasibility study (c.£5m)

Workstream 3:
- Industry-university collaborations awarded

Workstream 4:
- Sector strategy report produced
- Skills report produced
- Skills and training courses started
- Network + projects started
- ESRC project started

Workstream 5:
- Engaged with at least 10 potential investors, with at least 5 submitting applications as part of the first round of investor partnership competitions
- Committed £10m (£5m gov + £5m private equity) of 1st round of funding for start ups

Outputs (2022-23)

Workstream 1:
- Continued collaboration between 5 glass sector organisations
- At least two international partners involved in the delivery of the facility
- £22m match funding reached
- Pilot glass facility operational by 2023, with programme of R&D projects underway and a sustainable business plan

Workstream 2:
- 40 partnerships (commercial and non-commercial) between organisations from different foundation industry sectors
- 30 feasibility projects completed successfully
- 7 CRD projects at a mid-point review
- 5 cross sector demonstration projects started

Workstream 3:
- Industry-university projects initiated

Workstream 4:
- 20 combined industry and academic engagement activities delivered
- 20 early stage (TRL2-3) research projects progressed/ completed through Network+
- ESRC projects progressed/ completed
- Skills and training courses progressed/completed

Workstream 5:
- Privately funded projects progressed against milestones (1st round)
- Committed a further £10m (£5m gov + £5m private equity) of funding for a 2nd round for start ups with resource and energy efficiency technologies

Outputs (2024)

Workstream 1:
- Up to four established international partners actively engaged with the facility through funding or direct contracts

Workstream 2:
- 7 CR&D projects completed
- 5 cross sector demonstration projects completed
- Match funding delivered to target across all competitions

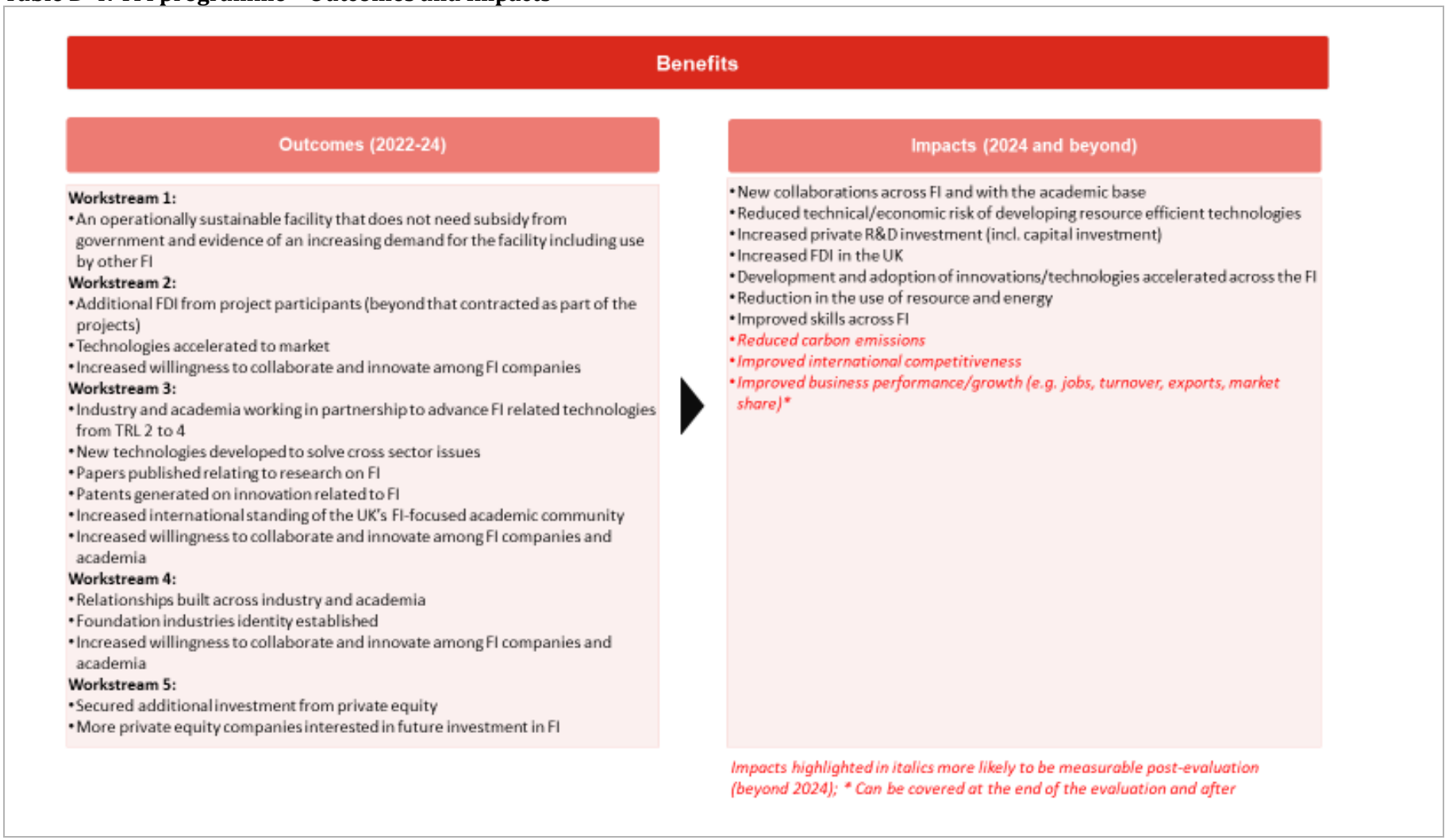
Workstream 3:
- Industry-university projects progressed/completed

Workstream 4:
- 40 combined industry and academic engagement activities delivered
- Network+ and ESRC projects completed
- Platform established for the creation of an industry supported council to address common challenges
- Skills and training courses completed

Workstream 5:
- Privately funded projects progressed against milestones (1st and 2nd rounds)

Source: SQW; UKRI; Note: timelines and some outputs may change to account for Covid-19 and other aspects coming to light

Table D-4: TFI programme – Outcomes and Impacts



Source: SQW; UKRI

Table D-5: TFI programme – Underlying drivers, assumptions, alternative/ complementary explanations

Underlying drivers and assumptions

Strategy

- Capital intensity, high costs and long investment cycles of FI inhibit the development and adoption of new technologies
- Information failures limit access to private finance, facilities and prevent collaboration between companies in FI (B2B) and the research base (B2R)
- There are common technologies and processes that can be used across some of the six sectors
- Businesses recognise existence of common challenges across FI and are motivated to seek common solutions
- Academics recognise existence of common challenges across FI and are motivated to seek common solutions

Delivery

- Programme activities are implemented as planned
- 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
- Collaborations are effective and with the right organisations
- There are appropriate governance and management structures in place to meet the operational demands of the programme
- Competition applications are of sufficient quality and balanced across the six sectors
- There are no gaps/ deficiencies in the monitoring data collected
- Mechanisms exist for shared learning and knowledge across and within workstreams

Benefits

- The amount of ISCF funding relative to the size of the six sectors is sufficient to make a difference to intended outcomes/impacts
- Investments would not have happened at all or not as quickly
- Increased innovation, collaborations, private investment etc. translate into increased international competitiveness and reduced carbon emissions
- Potential tension between improving economic output (and competitiveness) and reducing carbon emissions
- Programme timescales (2020-2024) are sufficient to realise outcomes and impacts
- The programme focus on recycling/ material reuse, and manufacturing materials in more efficient manner will minimise environmental impacts
- Technologies and knowledge developed through the programme is relevant for other sectors, resulting in spillovers
- Technologies work at demonstrators and then industrial scale (scaling up)
- Barriers to adoption of technologies are addressed

Alternative/ complementary explanations

Wider policy influences:

- Wider government policy influences innovation and sustainability e.g. incentives to reduce energy use

Other programmes:

- Other UKRI/IUK/BEIS programmes accessed by TFI ISCF programme beneficiaries

Market conditions:

- Sector-specific market conditions (e.g. firm characteristics, market structure, regulations, and industry-specific shocks) influence competitiveness
- Wider economic, social and political conditions (e.g. Brexit, COVID-19) influence development of technologies and business benefits
- UK's international competitors continue to invest heavily to support their respective FI and related sectors (e.g. technology, manufacturing), making it harder for the UK to compete

Inherent behaviour/actions:

- Internal business factors influence benefits, such as development and adoption of new technologies
- Technologies and knowledge generated is not the result of TFI programme funding per se, but from other/previous R&D
- Collaborations are not new but from existing supply chains and networks
- Companies would collectively invest in mutually beneficial facilities, e.g. in partnership with universities

Source: SQW; UKRI

Figure D-1: Theory of change for TFI programme workstream 1

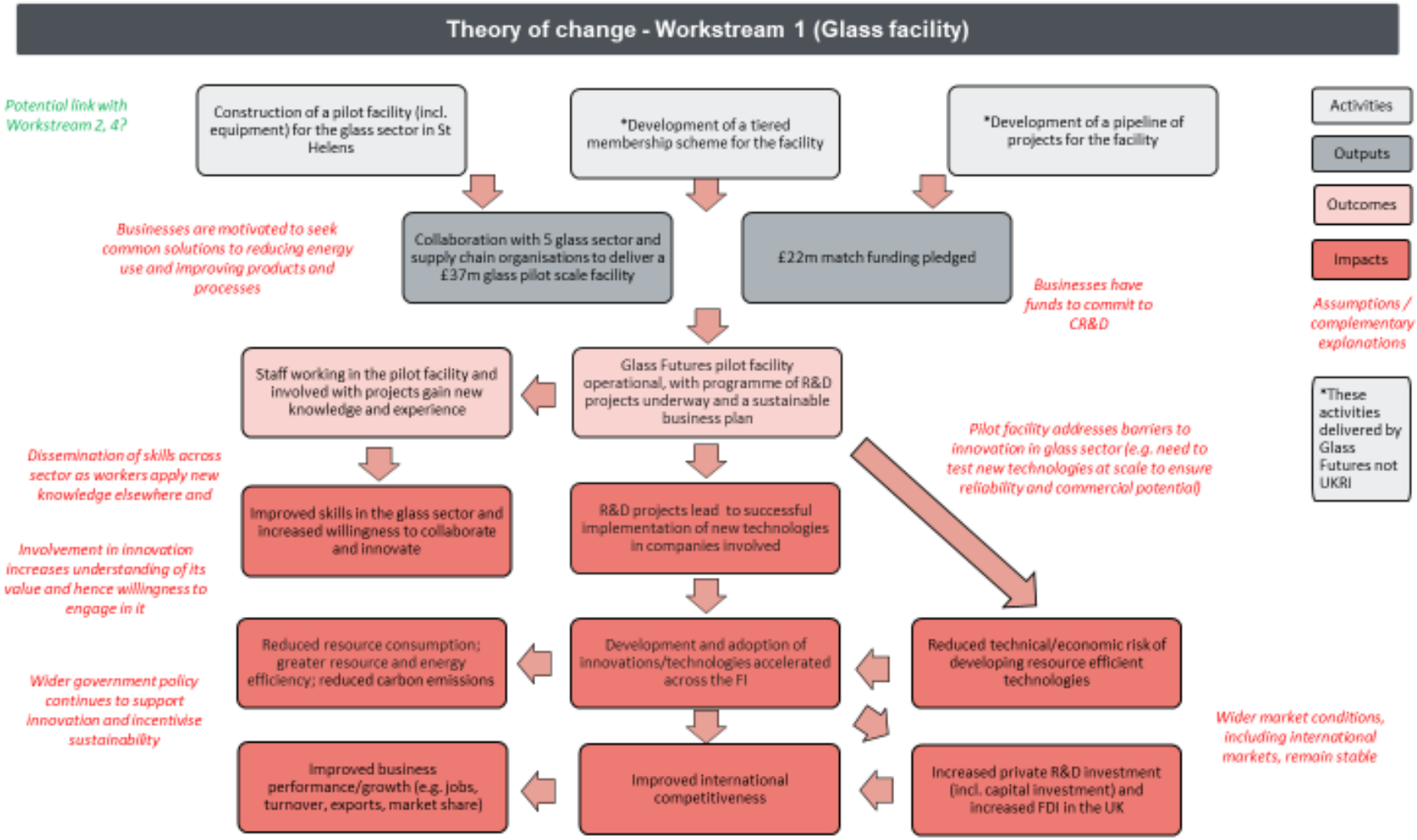


Figure D-2: Theory of change for TFI programme workstream 2

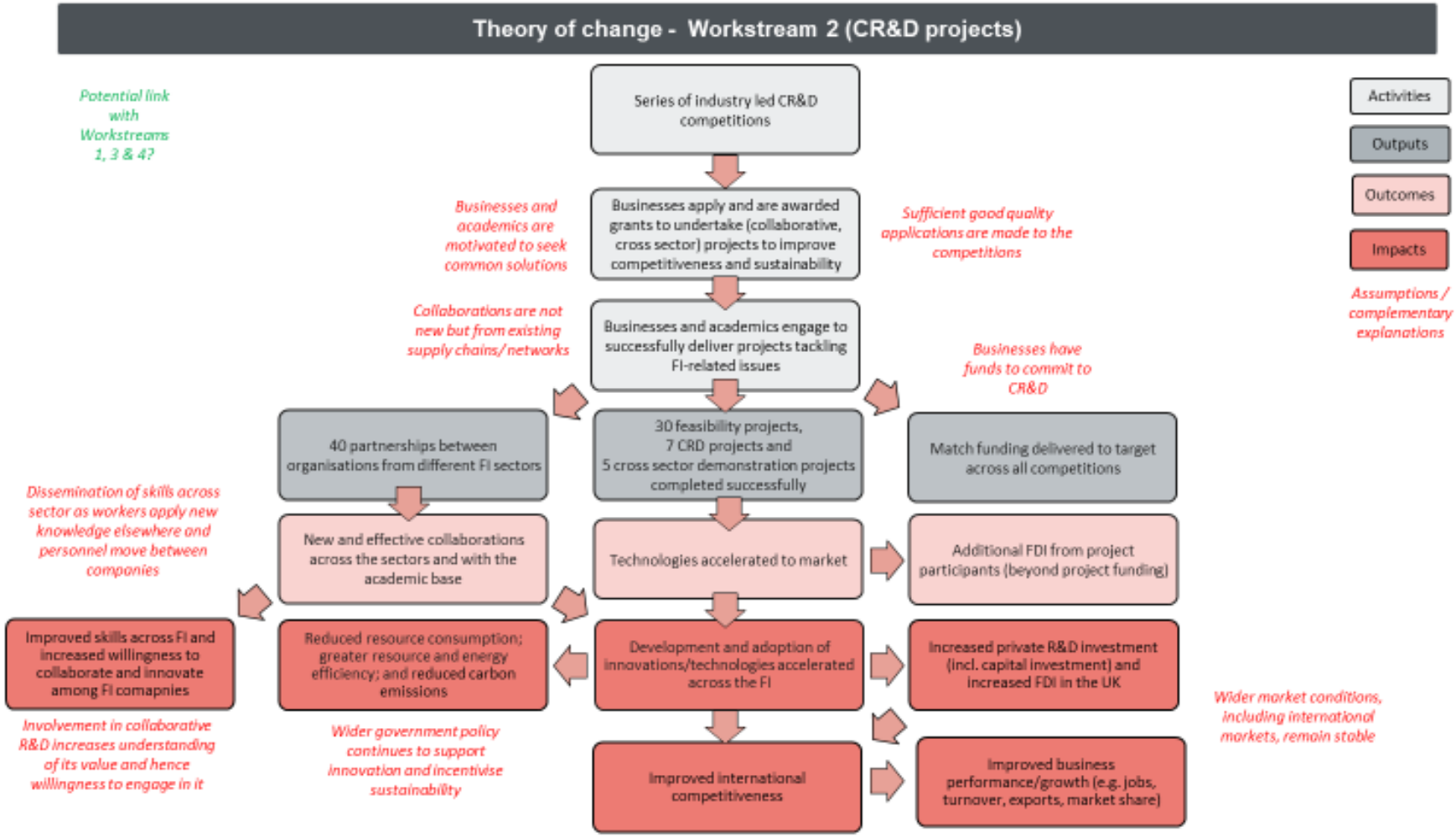


Figure D-3: Theory of change for TFI programme workstream 3

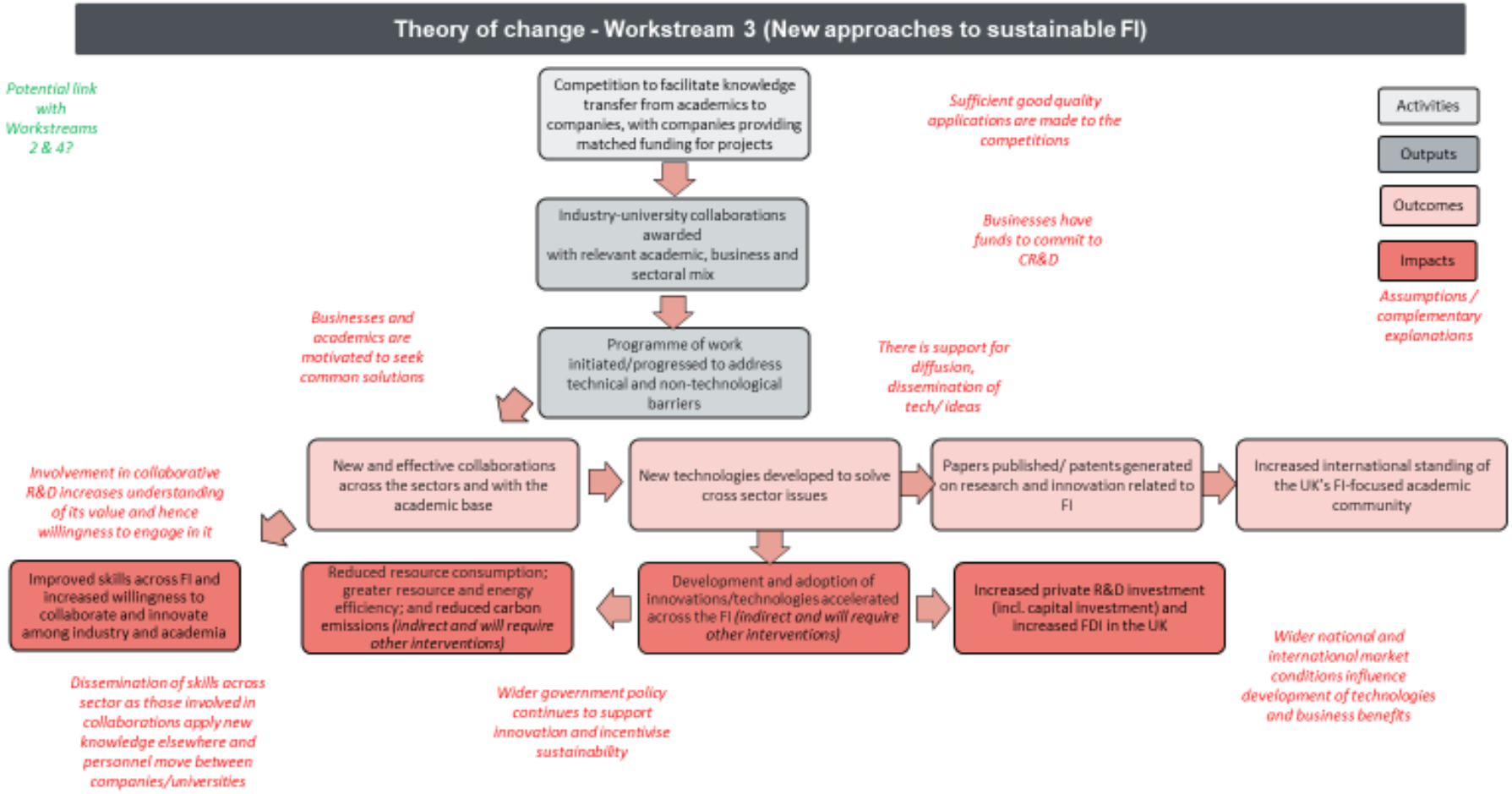


Figure D-4: Theory of change for TFI programme workstream 4

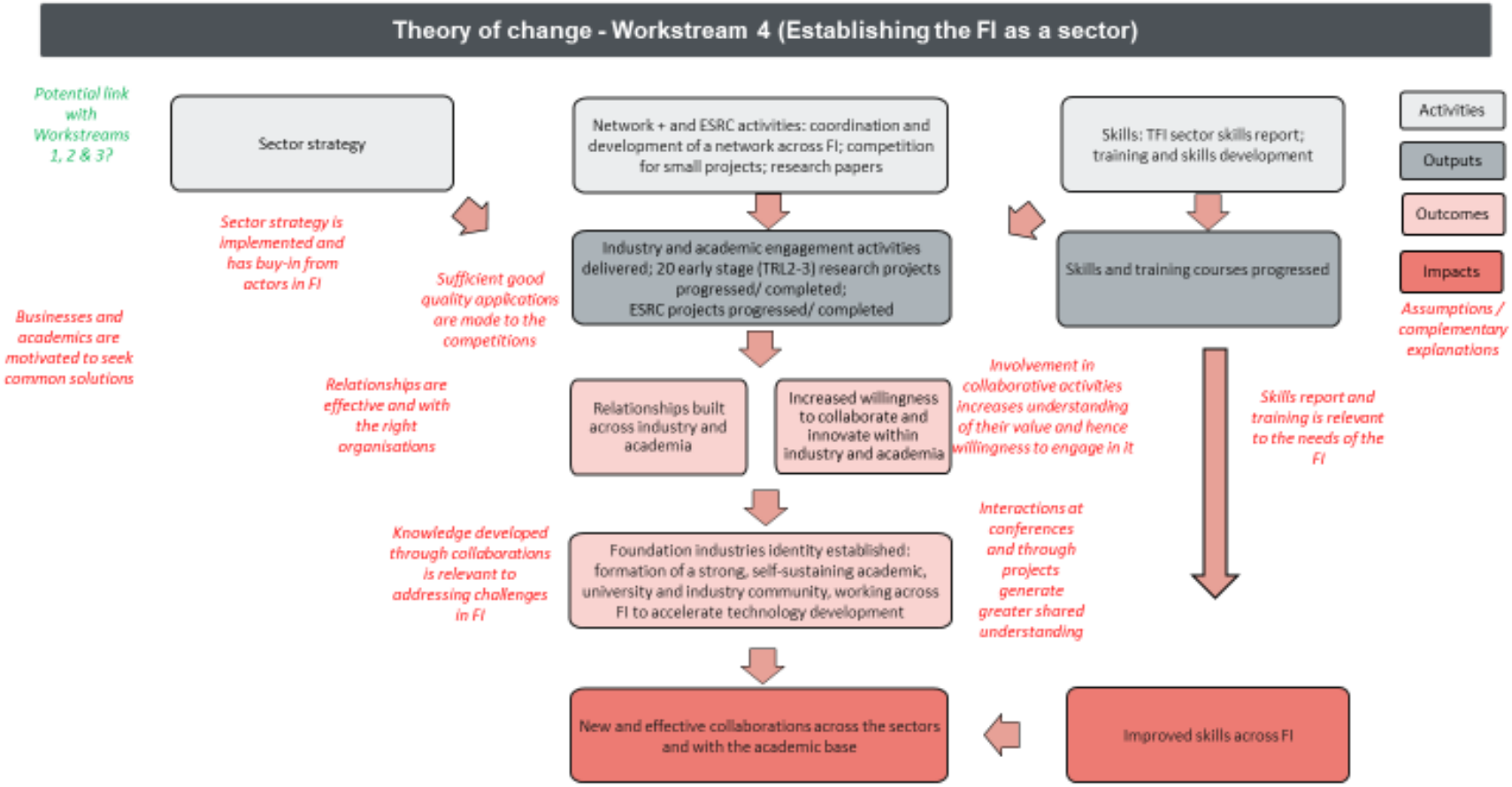
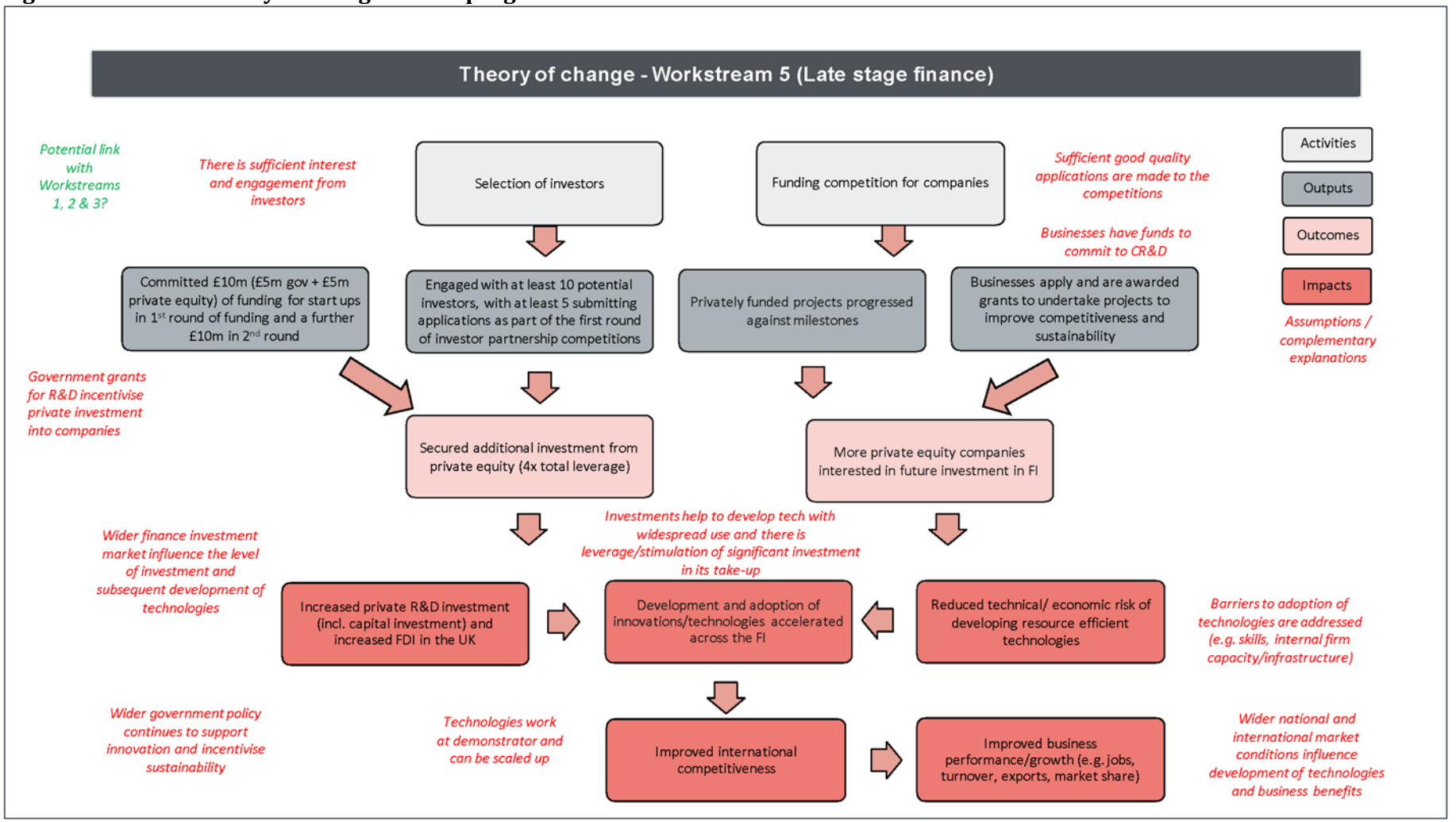


Figure D-5: Table: Theory of change for TFI programme workstream 5



Annex E: Data collection

E.1 The table below focuses on monitoring of inputs and outputs that align with the TFI programme logic model. The table does not cover data collection for all outcomes and impacts as these are covered in section 5 of the main report.

Table E-1: Key indicators – Inputs and outputs

#	Indicator	Source	Responsibility
	Inputs		
1	Amount of ISCF funding (by workstream) (£)	Programme monitoring	TFI team
2	Amount of industry matched funding (by workstream) committed and spent (£)	Programme monitoring	TFI team
3	Amount of other public funding (by workstream) (£)	Programme monitoring	TFI team
	Outputs		
4	Glass pilot scale facility delivered in terms of progress against milestones (W1)	Programme monitoring, including against Glass Future KPIs (quarterly reporting) and Benefits Realisation Plan (Benefit 4 – Delivery of an R&D scale up facility focused on glass)	TFI team
5	Number of CR&D competitions (W2)	Programme monitoring	TFI team
6	Number of CR&D competition applications, awards made (W2)	Programme monitoring, including competition Funders Panel and successful/unsuccessful application forms	TFI team
7	Number of CR&D competition awards (W2)	Programme monitoring, including competition Funders Panel and successful/unsuccessful application forms	TFI team
8	Value of CR&D grants awards (£)	Programme monitoring, including competition Funders Panel	TFI teams
9	Number of partnerships developed, including cross-sectoral (W2)	Programme monitoring, including against Benefits Realisation Plan (Benefit 9 – Closer collaborations across the Foundation Industries)	TFI team

#	Indicator	Source	Responsibility
10	Number of projects progressed / completed (W2)	Programme monitoring (by monitoring officers)	TFI team
11	Number of industry-research collaborations established (W3)	Programme monitoring	TFI team
12	Number of industry-research projects progressed/completed (W3)	Programme monitoring	TFI team
13	Number and types of reports produced (e.g. sector strategy, skills) (W4)	Programme monitoring, including against Network + programme KPIs	TFI team
14	Number of industry and academic engagement activities delivered (W4)	Programme monitoring, including against Network + programme KPIs	TFI team
15	Number of research projects progressed/ completed (W4)	Programme monitoring, including against Network + programme KPIs	TFI team
16	Skills and training courses progressed/completed (W4)	Programme monitoring (Network+ KPIs – SR to check)	
17	Number and type of firms funded (W5)	Programme monitoring, including competition Funders Panel and successful/unsuccessful application forms (from Hugh & IP team)	TFI team
18	Value of Government funding for firms with resource/energy efficiency technologies (£) (W5)	Programme monitoring, including competition Funders Panel (as above)	TFI team
19	Value of private funding for firms with resource/energy efficiency technologies (£) (W5)	Programme monitoring, including against Benefits Realisation Plan (Benefit 7 – Increased PE investment) (as above)	TFI team
20	Privately funded projects progressed against milestones (W5)	Programme monitoring (by monitoring officers) (as above)	TFI team

Source: SQW

Annex F: Stakeholder mapping

F.1 The tables below indicate some of the key stakeholders in the six FI sub-sectors and cover public and private organisations, including companies, Research and Technology Organisations (RTOs), and trade associations. The lists of stakeholders are not exclusive, and we anticipate they will be added to as the study progresses. The lists will provide a starting point for identifying possible interviewees for evaluation interviews.

F.2 There is a table per sub-sector. The tables may include organisations that fall outside a SIC code definition of a sub-sector. The Challenge is expected to involve organisations from other sectors in order to address issues relating to innovation and sustainability. The final table covers organisations that do not obviously belong within one sector, but the sector-specific tables may also contain organisations that could represent more than one sector.

F.3 The tables were compiled on the basis of data from UKRI, scoping research and review by the evaluation team sector experts.

Table F-1: Stakeholders – Chemical sector

Stakeholder	Classification
Centre for Process Innovation	RTO
Chemistry Council	Trade association
Society of Chemical Industry	Trade association
Chemical Industries Association	Trade association
Royal Society of Chemistry	Professional association
Ineos	Industry
Thomas Swan & Co	Industry
Houghtons	Industry
Croda	Industry
Synthomer	Industry
Johnson Matthey	Industry
Unilever	Industry
BP (chemicals division)	Industry
Shell (chemicals division)	Industry
Robinson Brothers	Industry
Chemoxy	Industry
Cogent Skills	Not for profit
Total	**17**

Source: UKRI; SQW

Table F-2: Stakeholders – Cement sector

Stakeholder	Classification
Cemex UK	Industry
Hanson Cement	Industry
Breedon Cement	Industry
Lafarge Cement	Industry
Tarmac	Industry
BRE Group	Industry
Mineral Products Association	Trade association
Construction Products Association	Trade association
Total	**8**

Source: UKRI; SQW

Table F-3: Stakeholders – Ceramics sector

Stakeholder	Classification
Saint Gobain	Industry
Foseco	Industry
Morgan Technical Ceramics	Industry
DSF	Industry
Dyson Technical Ceramics	Industry
Lucideon	RTO
British Ceramic Confederation	Trade association
Total	**7**

Source: UKRI; SQW

Table F-4: Stakeholders – Glass sector

Stakeholder	Classification
Allied Glass	Industry
Pilkington	Industry
Encirc	Industry
Guardian Glass	Industry
Stoelzle Flaconnage Ltd	Industry
Saint Gobain	Industry
Stealthcase Oy	Industry
Ardagh Glass	Industry
Croxsons	Industry
Plowden & Thompson	Industry
O-I Manufacturing	Industry

Stakeholder	Classification
Beatson Clark	Industry
Glass Futures	RTO
British Glass	Trade association
Diageo	Industry
Total	**13**

Source: UKRI; SQW

Table F-5: Stakeholders – Metals sector

Stakeholder	Classification
National Physical Laboratory	RTO
The Welding Institute	RTO
Materials Processing Institute	RTO
Tata Steel	Industry
Celsa	Industry
Liberty Steel	Industry
Cast Metal Federation	Trade Association
Make UK	Trade Association
UK Steel	Trade association
Rio Tinto	Industry
Innoval	Industry
Charles Keen	Industry
Advanced Forming Research Centre (AFRC)	RTO
Aluminium Federation (ALFED)	Trade association
British Constructional Steelwork Association (BCSA)	Trade association
British Stainless Steel Association (BSSA)	Trade association
Confederation of British Metalforming (CBM)	Trade association
Galvanizers Association (GA)	Trade association
Timet	Industry
Aubert & Duval	Industry
Sandvik	Industry
Spartan Steel	Industry
Arconic	Industry
Institute of Materials, Minerals and Mining (IOM3)	Trade association
Total	**24**

Source: UKRI; SQW

Table F-6: Stakeholders – Paper sector

Stakeholder	Classification
Paper	Trade association
Paper Industry Technical Association	Trade association
Ahlstrom Munksjo	Industry
Arjo Wiggins	Industry
BillerudKorsnas	Industry
Carlson	Industry
Portals	Industry
Devon Valley	Industry
DS Smith	Industry
Fourstones Paper Mill	Industry
Glatfelter	Industry
Higher Kings Mill	Industry
Hollingsworth & Vose	Industry
Huhtamaki	Industry
Iggesund Paperboard	Industry
James Cropper	Industry
Kimberly Clark	Industry
Wepa Bridgend Paper Mill	Industry
Northwood Tissue	Industry
Palm Newsprint	Industry
Romiley Board Mill	Industry
Saica	Industry
Sapphire Paper Mill	Industry
Essity	Industry
Smurfit Kappa	Industry
Sofidel	Industry
Sonoco Stainland	Industry
St Cuthberts Paper Mill	Industry
Sundeala	Industry
Union Papertech	Industry
UPM	Industry
Vernacare	Industry
Weidmann Whiteley	Industry
Total	**33**

Source: UKRI; SQW

Table F-7: Stakeholders – cross sector / Industry 4.0

Stakeholder	Classification
Virtalis	Industry
Kuka	Industry
Lanner	Industry
SpryTech Blockchain and Security Technology	Industry
SMS Group UK	Industry
Virtual Reality Machine Training	Industry
Siemens	Industry
AMETEK Land	Industry
Honeywell	Industry
Ericsson	Industry
Institute of Measurement and Control	RTO
WRAP	Trade association
CRU	Industry
Total	**13**

Source: UKRI; SQW

Annex G: Methods review

Theory based impact evaluation options

G.1 Within the context of the original Specification for the evaluation, the available resource, proportionality of input, and managing the balance between robustness and accessibility, three other theory-based methods highlighted in the Magenta Book (see Figure G-1 below) were considered as potential options to inform the evaluation:

- **Process tracing** – A structured method examining a single case of change to test whether a hypothesised causal mechanism, such as that proposed by the Theory of Change, explains the outcome. The main purpose of process tracing is to establish whether, and how, a potential cause or causes influenced a specified change or set of changes. This evaluation method can be particularly useful where there is a small number of treated companies, the interventions have complicated or complex characteristics, or where a comparison group is not feasible. Whilst the TFI programme fits all these characteristics, and as such process tracing was seriously considered; the main issue with a process tracing approach lies in its limited ability to quantify impacts. Moreover, process tracing requires a lot of evidence to be generated. This includes the time needed to understand the methodology, develop and describe multiple hypotheses, collect and analyse evidence and report on findings. There is a danger that the task may become too great, and one or more hypotheses may not be properly tested.

- **Qualitative Comparative Analysis (QCA**) – is a methodology used to compare multiple cases and systematically understand patterns of characteristics associated with desired or undesired outcomes based on qualitative knowledge. QCA could be particularly useful in the context of TFI as it provides a rigorous methodology for understanding change across a small or intermediary number of cases. QCA does not require statistically significant sample sizes, and can therefore be applied in circumstances where there are too few cases to carry out conventional types of statistical analysis. Having said this, it can be difficult to predict at the start of a QCA study how much time or resources will be needed. This is because good practice means constantly going back and forth between the analysis, the cases and the theory of change. As such, QCA may not be appropriate for evaluations that need to be carried out to fixed timescales and/or with fixed budgets, as is the case for TFI. Further, the approach involves identifying cases with both positive and negative outcomes (so that the factors explaining outcomes can be tested fully), which may not be possible given the varied time-paths and routes to impacts across different workstreams.

- **Realist evaluation** – a 'realist evaluation' approach to the evaluation (which like Contribution Analysis is method-neutral and can involve mixed-methods), was not considered in detail owing to the time consuming and resource intensive nature of this

approach (which involves the need to develop context-mechanism-outcome' (CMO) configurations for each relevant outcome)

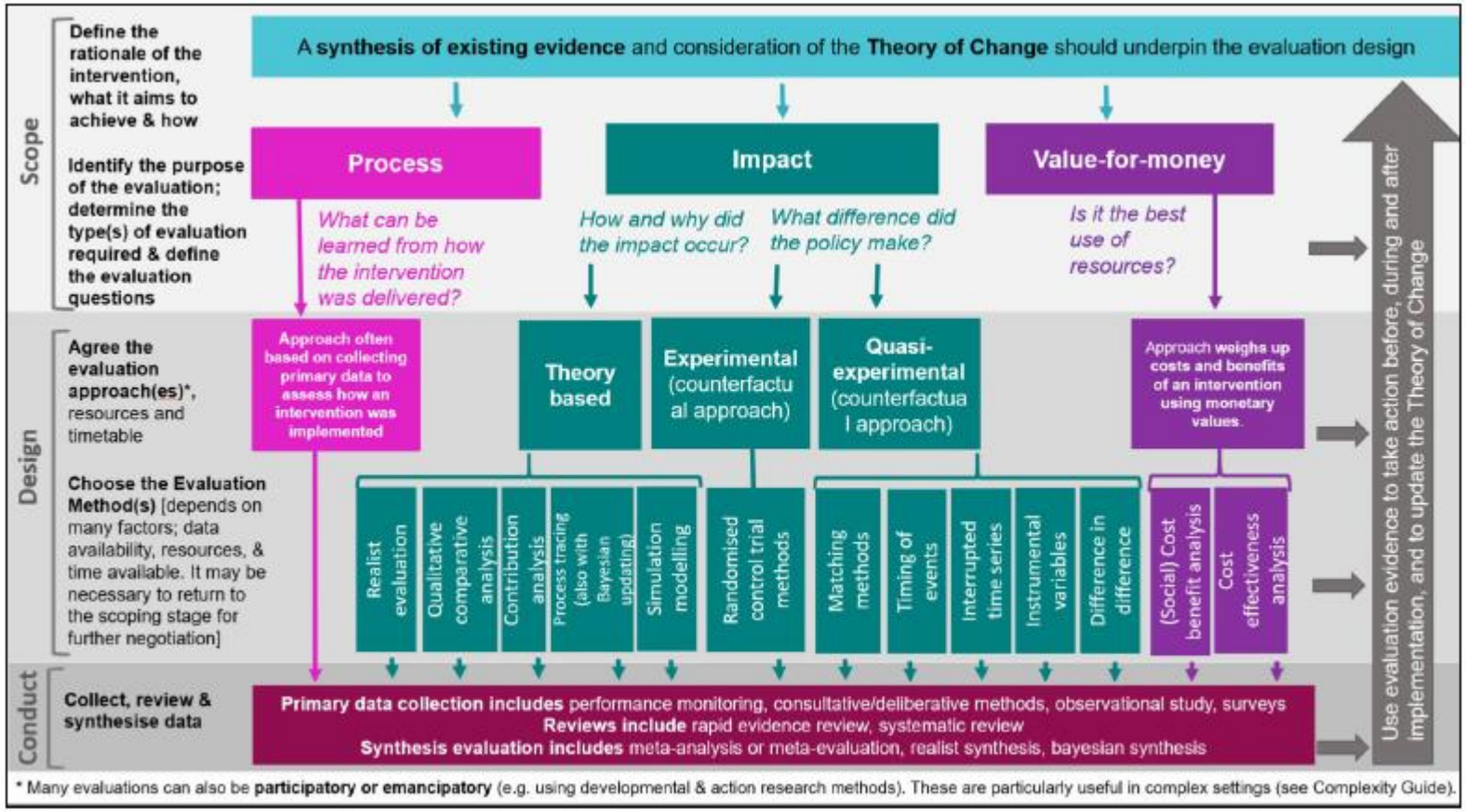
Quasi-experimental evaluation options

G.2 Where randomised evaluations are not feasible, as is the case with TFI, quasi-experimental approaches tend to be the next most robust option. In addition to the chosen methodology (i.e. DiD using two alternative comparison groups), two other quasi-experimental approaches were considered for this evaluation:

- **Regression discontinuity design** – this approach uses a threshold or cut-off between the treatment group and comparison group to analyse the difference in outcomes resulting from the programme at the margins of the 2 groups. Competitions including several Innovate UK programmes, often include a quality threshold (e.g. an assessment score of 70%). It uses a presumed randomness in allocation close to the threshold on either side (e.g. 69% and 71%) to proxy a random allocation process. However, this approach can only be used where there is sufficient sample size around the margin. This is not the case with TFI. First, a number of workstreams do not have any UAs, and second, even at the challenge level, the sample size is low. Moreover, this approach requires you to demonstrate that the discontinuity based on score is observed in the outcomes, but in no other potentially confounded variables (e.g. R&D intensity etc). This would be high improbably for TFI supported businesses.

- **Synthetic control methods** – were considered to test outcomes related to environmental impacts e.g. reduction in C02/other omissions. This method uses historical data to construct a 'synthetic clone' of a group receiving a particular intervention. Differences between the performance of the actual group and its synthetic clone may then be used as evidence that the intervention has had an effect. In the context of TFI, it could be plausibly argued that Foundation Industries contribute to a large share of UK's emission. As such, this approach would involve comparing the UK to its synthetic version using secondary data. There are two interrelated issues with this. First, environmental impacts take time, and so may not be visible in timescale of this evaluation. Second, secondary datasets which provide data on CO2/other emissions (e.g. Eurostat and OECD greenhouse gas emissions data) are associated with time lags. Currently, the latest available data is for the year 2018, a lag of more than 2 years. If the analysis was to be done in 2024, it would consider data up until 2022 only, and as such, unlikely find any noticeable effects.

Figure G-1: Scoping, designing and conducting an evaluation



Source: Magenta Book (2020)

Annex H: Scenario analysis

Introduction

H.1 Scenario analysis is a way of testing the robustness of a plan by considering plausible extreme futures and testing whether the plan would be resilient to each future. For the evaluation, this enables us to test the robustness of the evaluation framework. The scenario work also helps to test the theory of change by providing greater detail regarding alternative explanations of change.

H.2 The detailed scenarios are presented below, followed by some further insights regarding the operating context of the foundation industries and some models that can help consider how the FI might respond.

The detailed scenarios

Baseline Scenario: Business as Usual

H.3 BAU is the plausible future that the FI sector is expecting, and has factored into its thinking/planning. In sum, the world moves gradually with slowing of the markets for the UK FI, innovation does not increase and is driven mainly by customer demand or provision of new adjacent technologies. Investment remains asset-based and new manufacturing assets are in the same places and similar scale to those of past decades. In addition:

- Global Demand grows more slowly than in previous decades and the focus of growth shifts to Asia leaving Europe and North America with very slow growth.
- There are fewer technology breakthroughs in the next 15 years as the focus of R&D investments is on other sectors
- The foundation industries have few new technologies under consideration compared to previous decades
- Environmental pressure results in policies that increase regulation but there is little policy innovation (i.e. carbon price increases but mechanism stays the same)
- Product innovation in the FI is mainly customer led and so the innovation focus is on pull for new products and capabilities without associated process improvement.
- UK Government intervenes to drive the availability of adjacent technologies (i.e. CCS, Hydrogen, Renewable electricity) and these are then adopted by FI
- Government acts in the education sector to provide a suitable labour force (through apprenticeships support and curriculum policy). Skills retention and renewal is also supported

- Most FI key UK markets (built environment, transport, aerospace) continue to develop on a track that matches the past two decades. FMCG packaging changes rapidly as plastic packaging transfers to paper via consumer action following the Attenborough effect
- The full potential for digitalization is not considered and it is focused on achieving productivity growth
- Current supply chains remain stable with similarly size manufacturing plants and geographic locations
- The majority of innovation in the FIs is carried out in the high technology parts of each sector. This technology is then evaluated and adopted in part by the commoditized parts of the sectors at a slower speed where it diffuses based on longer investment cycles
- The current model for asset-based financing will remain similar in structure and will continue to be available to all parts of the FIs
- The implementation of the new EU trade agreement and subsequent sectoral negotiations result in limited damage to the FIs.

Scenario One: Constant Flux

H.4 In this world there are no periods of stability because of constant external changes affecting the FI. Short periods of high demand and high throughput are rare and don't last. Downturns are often surprising (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.

H.5 The general premise of the business as usual 13 baseline observations holds true.

External

H.6 In addition to the baseline conditions there is a constant background activity that creates mid-level disruption that can be characterized as:

- Interruptions in material flow caused by geo-political factors, extreme climate events, economic pressures changing feedstock price and availability.
- Energy availability is uncertain – the transfer from redundant supply sources (coal, old nuclear) to new plants is not smooth causing rolling blackouts, geopolitics causes gas supply interruptions, speed of implementation of renewable sources is interrupted.
- As neighboring FI suppliers hit lowering of demand they respond to ensure capacity targets are met by exporting / dumping into the UK market undercutting local FI. It takes time for government to respond and restore market equilibrium.

- The expected growth in the customers of the UK FI is slow to materialize as the required new trade agreements take longer to implement than predicted and do not always include favourable terms for UK FI customer sectors and local demand growth is sluggish.
- Customer demand fluctuates and the changes are driven by things such as: the Attenborough effect (avoidance of plastics), long term pandemic driven consumer behaviour changes (building use conversion), government policy effects (move away from diesel and towards electric vehicles).

Internal

H.7 As a result of the constantly changing operating conditions FI experience few periods of max profit-making when output and process conditions are optimal. FI finds it difficult to be clear about what technology and R&D is appropriate to invest in and how to maintain consistent innovation investment as profits rise and fall.

Alternative / Complementary explanations

Wider policy influences:

- Wider government policy influences innovation and sustainability e.g. incentives to reduce energy use
- Government policy fails to be consistent over sufficient periods to encourage investment
- Government actively chooses not to have policy and allows the market to decide.

Market conditions:

- Sector-specific market conditions (e.g. firm characteristics, market structure, regulations, and industry-specific shocks) influence competitiveness
- Wider economic, social and political conditions (e.g. Brexit, COVID-19) influence development of technologies and business benefits
- UK's international competitors continue to invest heavily to support their respective FI and related sectors (e.g. technology, manufacturing), making it harder for the UK to compete.

Inherent behaviour/actions:

- Internal business factors influence benefits, such as development and adoption of new technologies
- Technologies and knowledge generated is not the result of TFI programme funding per se, but from other/previous R&D

- Collaborations are not new but from existing supply chains and networks
- Collaborations emerge rapidly under stress and then fall away – only instant successes will stick
- Companies would collectively invest in mutually beneficial facilities, e.g. in partnership with universities
- Governments force rapid and massive tech innovation under short term stress conditions
- UK falls into negative rachet sequence of losing market share on each disruption cycle.

Other programmes:

- Other UKRI/IUK/BEIS programmes accessed by TFI ISCF programme beneficiaries.

Scenario Two: Constrained Technology Flow Scenario One: Constant Flux

H.8 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.

External

H.9 UK Government enhances its focus on high tech, financial and pharmaceutical sectors. Hence, the FI sector struggles to get meaningful follow-on or future R&D and innovation support. Carbon accounting by HMG excludes import costs and includes export costs. In this situation innovation investments outside of the UK means that newer manufacturing technology in Europe, Turkey and North Africa can make lower carbon products and import them to the FI customers in the UK, who prefer higher tech, lower carbon feedstocks (from importers).

H.10 Innovation underwritten by non-UK governments develop new formulae for creating low carbon cement / steel / paper etc. The innovations are protected by those governments resulting in competitive advantage outside of UK.

H.11 The main FI UK customers (Automotive, Aerospace etc.) decide to 'offshore' their manufacturing to Europe where they buy in FI feedstocks locally.

H.12 New manufacturing process equipment essential to the transformation of the FI is mainly developed in China with state funds and exports are restricted. As China drives to hit its Net zero by 2060 goals, all new equipment is needed in China and so availability elsewhere is restricted by local policy, economics (scale opportunities and returns are greatest in China's economy) and rate of production.

H.13 Core materials reduce in availability by more than 30% from current levels and the resulting price increases impact profit models and reduce investment available for innovation

H.14 Factors that influence core material availability include:

- Geo-political factors – keeping control of strategic materials, climate legislation
- Desire by China, Russia etc. to weaken westernized economies
- Global agreements on coal / ore / limestone extraction limits
- Transportation costs spiral per tonne and these are heavy bulk items.

Internal

H.15 Almost all of the UK FI are in non-UK ownership – their boards are not influenced by UK government incentives and elect to invest in bigger / faster growing markets.

H.16 UK FI sector is too small to achieve the returns required from investors looking to implement the improvements

H.17 The local UK markets are too small and fragmented. At the same time, the ability to create UK export markets for the FI to is too competitive / costly / tariff constrained

H.18 UK FI needs for innovation and scale up is not aligned to the asset investment cycle

H.19 There is an expectation that sunk cost in existing assets need to be recouped producing current outputs before re-investment can be justified

H.20 New breakthroughs could be 10 years too early/late to fit into possible re-investment cycles e.g. Low Carbon Cement

H.21 UK FI chooses to lead the world towards a circular FI ecosystem driven by necessity of sustaining security of supply. After the key breakthroughs are identified in the innovation process they require significant financing to implement and scale.

Alternative / Complementary explanations

Wider policy influences:

- Wider government policy influences innovation and sustainability e.g. incentives to reduce energy use

Market conditions:

- Sector-specific market conditions (e.g. firm characteristics, market structure, regulations, and industry-specific shocks) influence competitiveness
- Wider economic, social and political conditions (e.g. Brexit, COVID-19) influence development of technologies and business benefits

- UK's international competitors continue to invest heavily to support their respective FI and related sectors (e.g. technology, manufacturing), making it harder for the UK to compete; *access to raw materials, technology and finance are restricted*
- Asia growth sucks in all international companies activities
- Customers choose to offshore major FI customer sectors

Inherent behaviour/actions:

- Internal business factors influence benefits, such as development and adoption of new technologies
- Technologies and knowledge generated is not the result of TFI programme funding per se, but from other/previous R&D
- Collaborations are not new but from existing supply chains and networks
- Companies would collectively invest in mutually beneficial facilities, e.g. in partnership with universities
- Research all focuses on the speciality sectors which are needed for material security and national protection
- New research collaborations follow security alliances (for example NATO or other groupings – Boeing and Airbus)
- Investment timing windows shrink making research program timing alignment critical and harder

Other programmes:

- Other UKRI/IUK/BEIS programmes accessed by TFI ISCF programme beneficiaries

Scenario Three: Flourishing Internally Driven

H.22 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.

External

H.23 Supply of renewable/sovereign materials undercuts the costs of virgin /imported alternatives

Internal

H.24 The FI sector in the UK is vigorous, with a coordinated innovation ecosystem.

H.25 The FI sector becomes a smaller part of the overall economy while being outgrown by other sectors.

H.26 In this innovative ecosystem technology breakthroughs are cheaply and effectively harnessed to allow for re-use of core feedstocks – concrete, steel, chemicals.

H.27 FI become the system that provides (re-cycles and renews) fundamental core molecules in service of the Nation – "The Foundation Service" supporting their main customers as they servitize and become circular.

Alternative / Complementary explanations

Wider policy influences:

- Wider government policy influences innovation and sustainability e.g. incentives to reduce energy use
- Government sees this provides competitive advantage for UK export model on Low Carbon goods
- Policy has to shift to support circular foundation materials including new sectors such as remanufacturing equipment.

Market conditions:

- Sector-specific market conditions (e.g. firm characteristics, market structure, regulations, and industry-specific shocks) influence competitiveness
- Wider economic, social and political conditions (e.g. Brexit, COVID-19) influence development of technologies and business benefits
- New technologies and services influence economy, society and policy – remake steel and have to find new markets (in UK such as steel frame social housing)
- UK's international competitors have to invest heavily to support their respective FI and related sectors (e.g. technology, manufacturing), in order to compete with UK

Inherent behaviour/actions:

- Internal business factors influence benefits, such as development and adoption of new technologies
- Technologies and knowledge generated is only partly the result of TFI programme funding and is heavily influenced by other/previous R&D

- New collaborations grow with advanced customers (net zero automotive etc.)
- Companies and supply chains would collectively invest in mutually beneficial facilities (e.g. in partnership with universities, waste industry)
- Ability to export new technologies that are developed in UK
- Collaborations based on existing supply chains and networks and are massively extended (for instance to have material control focus).

Other programmes:

- Other UKRI/IUK/BEIS programmes accessed by TFI ISCF programme beneficiaries
- Low carbon exports link to soft power initiatives (FCO and MOD)

Scenario Four: Flourishing Externally Fed

H.28 In this world UK government research and industry have solved the problems of 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.

External

H.29 Energy supply of renewable electricity undercuts the costs of hydrocarbon-based alternatives

Internal

H.30 The FI sector in the UK is vigorous, with a coordinated innovation adoption ecosystem (to enable the FI to benefit from the externally generated innovations).

H.31 It becomes a smaller part of the overall economy while being outgrown by other sectors.

H.32 Technology breakthroughs are cheaply and effectively harnessed to capture the benefits from low carbon, low cost energy.

H.33 FI becomes the system that takes low carbon energy and imported molecules to deliver materials in service of the Nation – "The Foundation Service" supporting their main customers as they servitize and become circular.

Alternative / Complementary explanations

Wider policy influences:

- Wider government policy MUST generate these technologies

- Wider government policy influences innovation and sustainability e.g. incentives to adopt innovations
- Government sees this provides competitive advantage for UK export model on Low Carbon goods

Market conditions:

- Sector-specific market conditions (e.g. firm characteristics, market structure, regulations, and industry-specific shocks) influence competitiveness
- Wider economic, social and political conditions (e.g. Brexit, COVID-19) influence development of technologies and business benefits
- UK's international competitors have to invest heavily to support their respective FI and related sectors (e.g. technology, manufacturing), in order to compete with UK

Inherent behaviour/actions:

- Internal business factors influence the benefits, through variation in the adoption of the new external technologies
- Technologies and knowledge generated is not the result of TFI programme funding per se, but from other/previous R&D
- New collaborations grow with advanced customers (net zero automotive etc.)
- New collaborations can evolve across sub-sectors or in local geographic regions (clusters) to increase adoption competence
- Companies and supply chains would collectively invest in mutually beneficial facilities (e.g. in partnership with universities, private research etc)

Other programmes:

- Other UKRI/IUK/BEIS programmes accessed by TFI ISCF programme beneficiaries
- Low carbon exports link to soft power initiatives (FCO and MOD)

Insights

Critical Insight

H.34 There is one critical insight, namely a failure to understand influences that will stop BaU continuing in the 2020's:

- Reports assume sustainability / climate change actions will NOT impact the Business as Usual direction and actions
- Reports DO NOT mention servitisation in upstream industry development OR provision to customers
- The signals (from Re-think & other external reports) that we are already in a period of significant disruption have not been recognized in reports or most interviews
- Reports do not recognize or consider market interconnectedness and few account for potential Brexit effects beyond the obvious local sector impacts
- There is little recognition of the potential impacts of demographic shifts and/or labour market changes
- Expectation that there will be very little new plant build in UK/EU/NA most will be in Asia – to meet local demand
- New tech sustainability benefits will NOT be in UK
- Import of low carbon FI products will become hard to resist
- Financing will be harder to attract in UK
- UK FI assume they have little or no control over future
- Expect government/technology suppliers/customers to assist or provide support for change
- Assumption that size and scale of manufacturing plants is unchanged
- No account for distributed manufacturing
- Circularity is a visible future change but not considered as an active driver in the short term (also seen as not in control see 7 above)

Notable Insights

H.35 We identified **10 notable insights**, ranging from the view that Ceramics / Glass / Paper / Steel may be two speed industries with a smaller high tech sector and a traditional lower tech / commoditized sector, with the expectation that changes and improvements will trickle down, to the worry over a lack of Foundation Industry Catapult to the observation that the FI cannot afford to be innovative AND cannot afford NOT to be innovative (not enough scale or local ownership to invest, but without investment a decline is inevitable).

- Appears that Ceramics / Glass / Paper / Steel may be 2 speed industries with a smaller high tech sector and a traditional lower tech / commoditized sector.
- Some expectation that changes and improvements will trickle down

- Commoditized sectors are felt to be more at risk?
- Technology customers (not the manufacturers) are driving innovation in the high tech sectors
- Problem Understanding vs Action (response) consensus is unclear
- Expectation that there is 'quiet' planning going on at CEO level but not being shared with markets, governments etc. for fear of instigating the change from BaU
- Impact of Attenborough effect on staff morale, retention and recruitment in plastics industry, but little fear of spreading to other FIs
- There is not a FI catapult to match the High Value Manufacturing catapult
- The FI cannot afford to be innovative AND cannot afford NOT to be innovative.

Other Insights

H.36 There are 29 other insights, with some of the leading observers pointing to the lack of debate around Bio-chemical manufacturing, Electro-chemical manufacturing, or Distributed manufacturing as forces that will shape the future of FI. A similar concern was voiced over the limited vision for the future of digital in the Foundation Industries. There is an interesting frustration felt about the FI inability to create demand for low carbon/sustainable products even when technology and capability is ready e.g. low/no carbon cement. Some observers pointed to the lack of companies acting as systems integrators to enable the benefits from synergies to be realized, based on the view that cross-sub-sector integration is one key future shift together with an envied look at other sectors that do have 'system integrators' (such as construction/aero/auto). The interactions between pace of change, very complex investment conditions and the culture that "real men spend capital", point to systemic challenges.

H.37 If Plastic is the new tobacco – who is next?

- What happens if and when public opinions swings suddenly?
- What are the possible switches that can make this change fast (in months)
- Who are the agitators for this?

H.38 There are a set of standard expected improvements in FI (for scenarios these are baked in)

- Specific tech process improvements – sector specific
- Carbon capture (and storage or use)
- Improvement in plant efficiency
- Availability of and switch to clean fuel (renewable electricity, biomass, hydrogen)

H.39 Bio-chemical manufacturing, Electro-chemical manufacturing, Distributed manufacturing are all missing

H.40 Inability to create demand for new (low carbon/sustainable) products even when technology and capability is ready e.g. low/no carbon cement

H.41 In high tech parts of FI sector potential customers are not always aware of possibilities (i.e. ceramics sector potential in batteries, ability to design packaging paper for >7 lives)

H.42 FI are not 'thinking through digital' except for automation. For example; Ability to utilise data across the life cycle (i.e. multi-life design)

H.43 Government access, awareness, understanding of the FI is often low, regional and outdated (for example assuming they are high volume employers). They are under focus mainly when in crisis.

H.44 Biorefining in the paper industry has not taken hold in the UK

H.45 In Asia (China) switch to new products and technologies can be fast (for example from single use plastic to paper for food – have the technology, equipment and political support)

H.46 UK FI are not ready to transfer to low price clean electrical energy

H.47 Chemical Industry is still on BaU: grow at scale and delay investments

H.48 Material Sovereignty in the future will drive UK investment (from Chemical industry)

H.49 Across the FI there is a lack of companies acting as systems integrators to enable the benefits from synergies to be realized

H.50 Paul Polman effect – Children of CEOs are creating impact through questioning and challenging

H.51 The Chemical industry will 'Bionize' in the near future

H.52 Customers are looking for 'Naturalness'

H.53 Chemical industry will have future rapid disruptions e.g. previous CFC effect

H.54 Steel – when cars move to becoming shared service the need for ore will drop by 70%

H.55 UK has lost its recycling capacity and exports and re-imports

H.56 Specialist knowledge in Steel (and FI) is ageing and localized

H.57 Glass – "money is made from the coatings"

H.58 Personalization requirements will drive (some) FI from economy of scale to small, local and modular

H.59 Level of experimentation is low (outside of what 'we already know')

H.60 "Real men spend capital" ingrained UK culture that promotes asset-based investment not radical change

H.61 Explosive and innovative markets will be in Africa and S. America

H.62 Many high value equipment makers for the FI are now in Asia / China AND the equipment manufacturers dominate the direction and pace of change

H.63 Potential pace of change compared to UK FI expectations. For example Cement industry does not expect a breakthrough for 20 years, food quality paper alternative to single use plastic from Zero to 100M units / year in 18 months in China.

H.64 CE needs better/different Building Information Management Systems (BIM)

H.65 Financing – Are ROI expectations changing as new tech / services dominate?

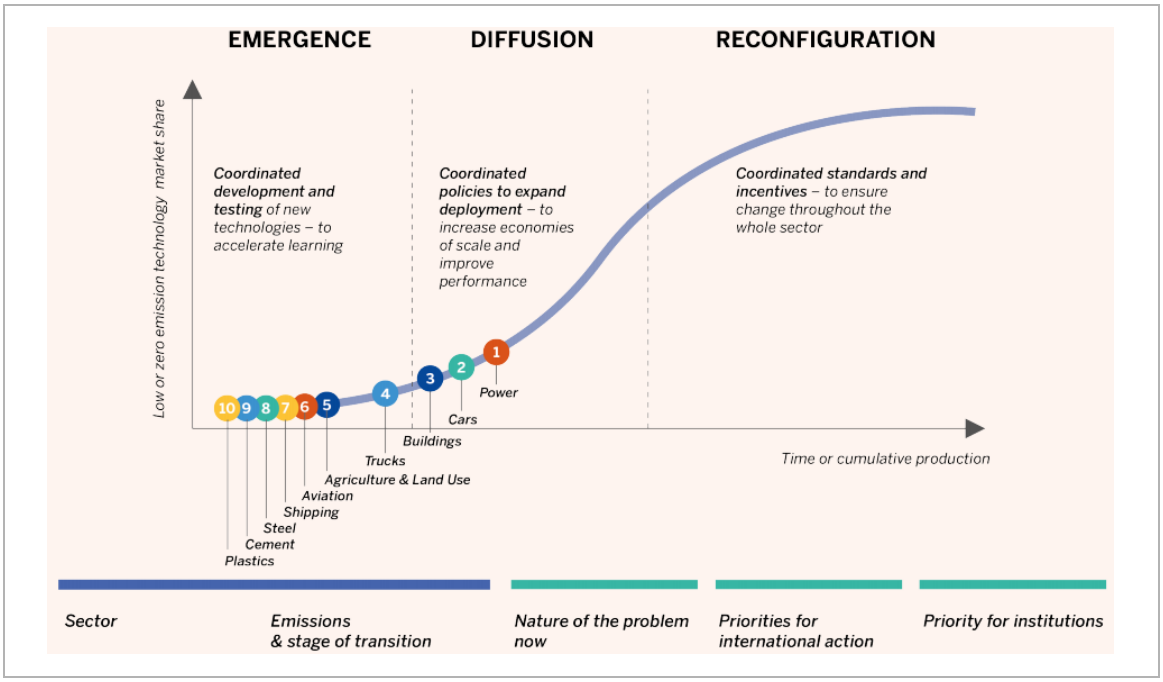
- Financing – Will overseas owned FI businesses invest or leave UK with 'stranded assets'?
- UK market too small for standard investment returns in a "low demand growth sector"
- UK has poor access to global markets
- Tech development in manufacturing equipment is conducted outside of UK and collaborations exclude UK and hence UK interests

Models to inform understanding of the FI

H.66 The research considered some models that may inform an understanding of the contextual factors that influence the FI and how the sector might respond:

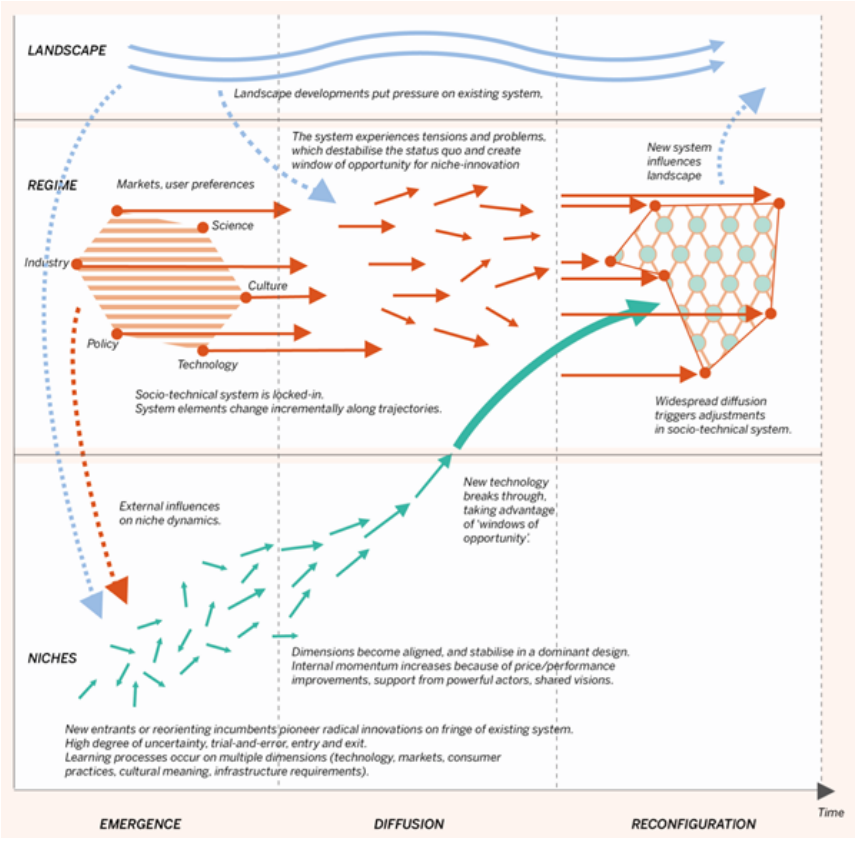
- The first model (see Figure H-1) offers a language to discuss how sectors may transition to a new system, emphasising stages from emergence through diffusion to reconfiguration. In terms of preparedness for transition to a low carbon economy, the FI sub-sectors are among the least prepared.
- The second, well-known, model for discussing disruptive transitions, known as the 'multi-level perspective' (Figure H-2**Error! Reference source not found.**), emphasises how the entire landscape can change, driven by '*incumbents (that) pioneer radical innovations on fringe of existing system*' (termed a 'regime shift'). Presuming that the landscape is changing for the FI, this implies a search for those niches that can drive regime shift (as opposed to a straight attack on the dominant business model).
- Third, a matrix that analyses the state of knowledge and the level of consensus on action (Figure H-3**Error! Reference source not found.**) is offered to help explain two key dimensions that shape how a sector may respond to an imminent disruptive transition. For the FI this model challenges the sector to determine whether it is an *experimentalist learning*, or has matured to *co-ordinated diffusion*, with significant implications on technology strategy.

Figure H-1: Progress of sectors' low carbon transitions, and priorities for coordinated international action



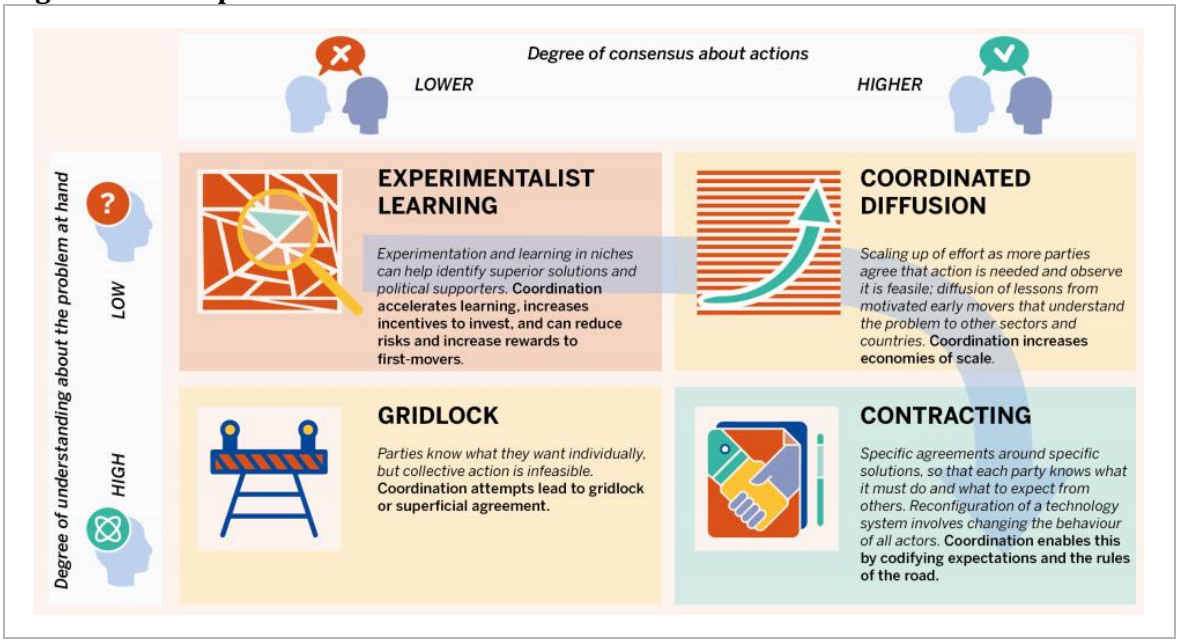
Source: Victor, D.G., Geels, F.W. and Sharpe, S., 2019, 'Accelerating the Low Carbon Transition: The Case for Stronger, More Targeted and Coordinated International Action', Figure 1, p14

Figure H-2: The multi-level perspective on sustainability transitions



Source: Victor, D.G., Geels, F.W. and Sharpe, S., 2019, 'Accelerating the Low Carbon Transition: The Case for Stronger, More Targeted and Coordinated International Action', Figure 2, p18

Figure H-3: Cooperation matrix



Source: Victor, D.G., Geels, F.W. and Sharpe, S., 2019, 'Accelerating the Low Carbon Transition: The Case for Stronger, More Targeted and Coordinated International Action', Figure 9, p34

References for scenario analysis

General

Absolute Zero (2019) Allwood, J.M., Dunant, C.F., Lupton, R.C., Cleaver, C.J., Serrenho, A.C.H., Azevedo, J.M.C., Horton, P.M., Clare, C., Low, H., Horrocks, I., Murray, J., Lin, J., Cullen, J.M., Ward, M., Salamati, M., Felin, T., Ibell, T., Zho, W., Hawkins, W. UK FIRES.

University of Cambridge. DOI: 10.17863/CAM.46075

A System Change Compass. Implementing the European Green Deal in a Time of Recovery. (2020)

Breaking the Code. Deciphering Climate Action Efforts in the Financial Sector (2020) James Mitchell, Lindsey Schafferer, Tyeler Matsuo & Radhika Lalit. Rocky Mountain Institute.

Evaluation of Transforming Foundation Industries, Industrial Challenge Fund (2020) SQW.

Industrial Decarbonisation & Energy Efficiency Roadmaps to 2050. Cross-sector Summary (2015)

RethinkX. Disruption, Implications, and Choices. Rethinking Humanity. Five Foundational Sector Disruptions, The Lifecycle of Civilizations, and the Coming Age of Freedom (2020) James Arbib & Tony Seba.

Accelerating the low carbon transition; Energy Transitions Commission report November 2019

Steel

Towards a Low Carbon Steel Sector; Energy Transitions Commission report March 2020

Mission Possible sectoral focus Steel: ETC Paper January 2019

Industrial Decarbonisation & Energy Effciency Roadmaps to 2050. Iron and Steel (2015)

Iron and Steel Technology Roadmap. Towards more sustainable steelmaking (Launch webinar, 08 October 2020) International Energy Agency.

Low Carbon Roadmap, Pathways to a CO2-neutral European Steel Industry (2019) The European Steel Association Eurofer.

Steel 2020. The All Party Parliamentary Group on Steel and Metal Related Industries. Forging a Future for the British Steel Industry. (2017) APPG.

Cement

Cement Sector Industrial Decarbonisation and Energy Efficiency Roadmap Action Plan (2017) Department for Business, Energy & Industrial Strategy.

Industrial Decarbonisation & Energy Effciency Roadmaps to 2050. Cement (2015)

Technology Roadmap. Low Carbon Transition in the Cement Industry (2018) OECD / International Energy Agency.

The Impact of Future Generation on Cement Demand: An Assessment Based on Climate Scenarios (2019) Clément Bonnet, Samuel Carcanague, Emmanuel Hache, Aymen Jabberi, Gondia Sokhna Seck & Marine Simoën.

UK Concrete and Cement Industry Roadmap to Beyond Net Zero (2020) Mineral Products Association, MPA UK Concrete.

Mission Possible sectoral focus Cement: Energy Transitions Commission Paper January 2019

Chemicals

Bulk Chemical Packaging Market: Global Industry Analysis, Size and Forecast, 2018 to 2027. (2018) FMI.

Chemicals 2025: Will the industry be dancing to a very different tune? (2017) McKinsey

Industrial Decarbonisation & Energy Effciency Roadmaps to 2050. Chemicals (2015)

Veronika Dornbur, Barbara G. Hermann, and Martin K. Patel (2008) Scenario Projections for Future Market Potentials of Biobased Bulk Chemicals. Environ. Sci. Technol. 2008, 42, 7, 2261–2267. https://doi.org/10.1021/es0709167

Mission Possible sectoral focus Plastics: Energy Transitions Commission Paper January 2019

Pulp and Paper

2030 Industry Manifesto (2020) Confederation of European Paper Industries Cepi.

Industrial Decarbonisation & Energy Effciency Roadmaps to 2050. Pulp and paper (2015)

The packaging, pulp and paper industry in the next decade (2019) McKinsey

The State of the Global Paper Industry. (2018) Environmental Paper Network.

Unfold the Future. The Forest Fibre Industry 2050 Roadmap to a Low-carbon Bio-economy (2011) Confederation of European Paper Industries Cepi.

Ceramics

Ceramics Industry. UK Manufacturing Review 2019/20

Industrial Decarbonisation & Energy Effciency Roadmaps to 2050. Ceramics (2015)

Glass

Industrial Decarbonisation & Energy Effciency Roadmaps to 2050. Glass (2015)

Unveiling future of £1.6bn glass industry (2019) St Helens Council

Background Reports

World Economic Forum Reports:

2.2 Fraying Rule of Law and Declining Civic Freedoms: Citizens and Civic Space at Risk

http://reports.weforum.org/global-risks-2017/part-2-social-and-political-challenges/2-2-fraying-rule-of-law-and-declining-civic-freedoms-citizens-and-civic-space-at-risk/?doing_wp_cron=1523538026.9695880413055419921875

4 scenarios for the future of civil society

https://www.weforum.org/agenda/2015/08/4-scenarios-for-the-future-of-civil-society/

5 facts you need to understand the new global order

https://www.weforum.org/agenda/2018/01/five-facts-you-need-to-understand-the-new-global-order/

Are we at risk of a financial crisis?

https://www.weforum.org/agenda/2019/10/regional-risks-to-doing-business-2019-reduce-risk-of-financial-crisis/

http://www3.weforum.org/docs/WEF_Regional_Risks_Doing_Business_report_2019.pdf

Global Risk Report 2020

http://www3.weforum.org/docs/WEF_Global_Risk_Report_2020.pdf

The Net-Zero Challenge: Global Climate Action at a Crossroads

https://www.weforum.org/reports/the-net-zero-challenge-global-climate-action-at-a-crossroads-part-1

Other reports

SITRA Global Megatrends: the most important trends of the 2020s

https://www.sitra.fi/en/news/here-they-are-the-most-important-trends-of-the-2020s/

The International Energy Agency WEO Energy (2018)

https://www.iea.org/reports/world-energy-outlook-2018

IMF: Carbon Calculus: For deep greenhouse gas emission reductions, a long-term perspective on costs is essential

https://www.imf.org/external/pubs/ft/fandd/2019/12/the-true-cost-of-reducing-greenhouse-gas-emissions-gillingham.htm

McKinsey: Climate risk and response: Physical hazards and socioeconomic impacts

https://www.mckinsey.com/business-functions/sustainability/our-insights/climate-risk-and-response-physical-hazards-and-socioeconomic-impacts?cid=other-eml-alt-mgi-mck&hlkid=432ae923e1e0463c8fa1c841a60aed5c&hctky=2251770&hdpid=71d6425d-b38b-4be9-b85a-c15ef324f00