Evaluation of the Industrial Strategy Challenge Fund

Baseline report

RAND Europe and Frontier Economics

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Prepared for UKRI

Executive Summary

The Industrial Strategy Challenge Fund (ISCF) is a mission-oriented research and innovation (R&I) programme which supports the development of solutions to major industrial and societal challenges facing the UK. The Fund is primarily delivered through a set of 20 'Challenges', each focusing on a pressing industrial and societal issue, with business and academic partners invited to bid collaboratively for projects that have the potential to contribute to addressing each Challenge. RAND Europe and Frontier Economics have been commissioned by UKRI to undertake a fund-level evaluation of the ISCF. The aim of this evaluation is to build an evidence base with which to judge the success and overall impact of the ISCF in order to:

- Inform ongoing and future improvements to the ISCF to maximise the value of public funding
- Demonstrate the return on investment to taxpayers
- Build the evidence base on the impact of mission-oriented and challenge-focused R&I support as part of UKRI's wider efforts to understand 'what works' in R&I policy and delivery

Alongside this evaluation, UKRI is also commissioning evaluations of each of the ISCF Challenges. We will be building on these Challenge-level evaluations, as well as collecting our own data, to support the Fund-level evaluation.

In the previous phase of the work, we developed an evaluation framework for the Fund-level evaluation, underpinned by a Theory of Change. This report sets out a baseline measurement for the evaluation. The aim of the baseline measurement phase of the evaluation is to review quantitative and qualitative data on the state of the UK R&I landscape in sectors relevant to the ISCF Challenges at the time of establishment of the ISCF. The baselining phase also aims to consider contextual factors that might impact upon the success of the ISCF, including potential barriers to, and enablers of, its implementation and delivery. The baselining phase will help to inform the impact evaluation of the ISCF – to be undertaken in later phases of the evaluation – by allowing us to compare the achievements of the ISCF to what was already in existence previously.

Baselining was conducted through four main methodologies: (i) a review of Challenge-level baseline reports, where available; (ii) analysis of secondary data sources, consisting of publicly available data (e.g. from the Office for National Statistics) and data shared with us by UKRI on the Fund and the wider portfolio of UKRI funded research; (iii) a network analysis looking at the connections made within the funded portfolio; and (iv) a series of five baselining workshops with stakeholders including Challenge Directors, award holders and sector-level representatives. We have structured the baseline findings around five thematic areas

identified in the evaluation framework (see RAND Europe and Frontier Economics 2021 for more details). A summary of the key baseline findings is also provided as a table in Annex E.

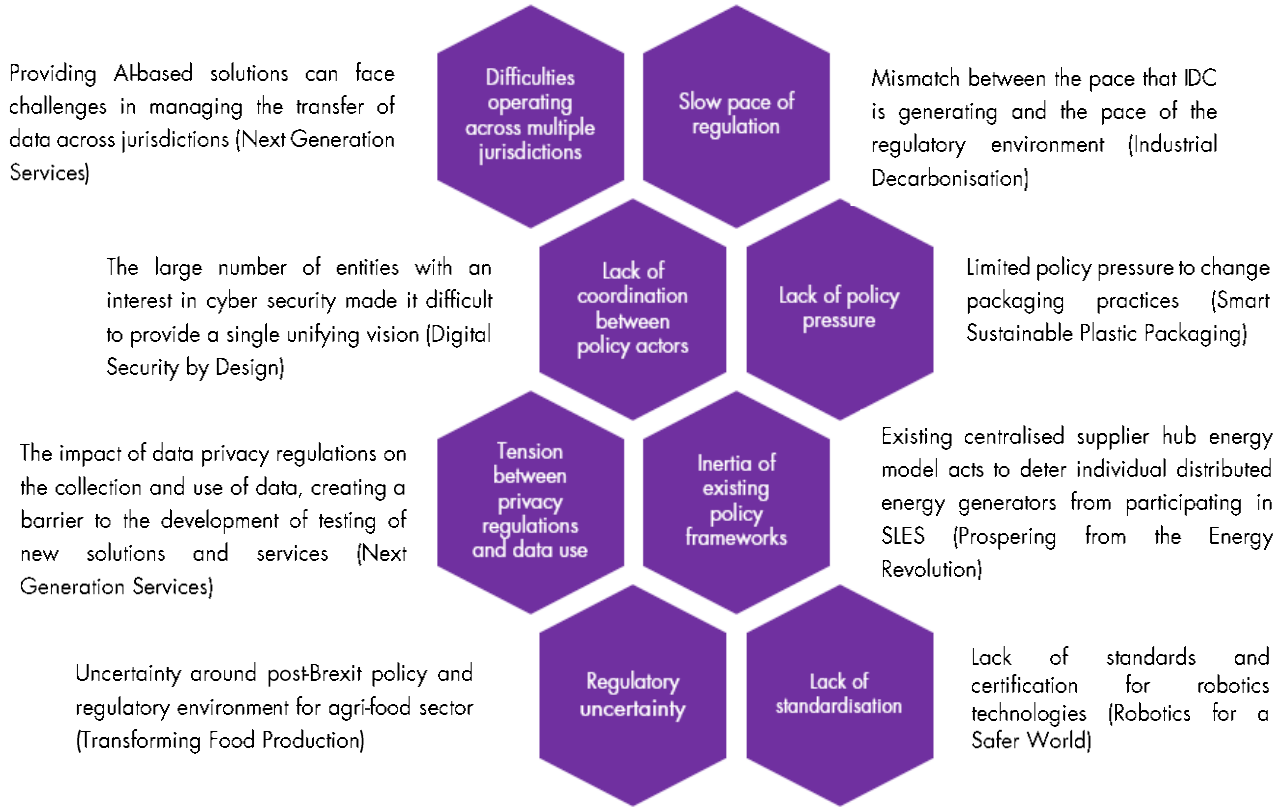
Creating knowledge and innovation pathways: A key aim of the ISCF is to create knowledge and advance progress of innovation towards adoption and use. This spans the generation of new knowledge outputs, the advancement and adoption of new technologies and innovations, engagement with different stakeholder groups – including industry, policymakers and the wider public – regarding knowledge and innovation outputs, and the promotion of evidence-based policymaking within the Challenge areas. In this area, we identify the following baseline findings:

- **New technologies and innovations were already being developed in many Challenge areas at baseline** but in most cases, ISCF-funded projects were at a relatively early stage of readiness at baseline, with most projects reporting Technology Readiness Levels (TRL) of 1 to 4, though even within individual Challenges TRLs often varied across different funding streams.
- **In terms of the patent activity of ISCF participant organisations, findings from Challenge-level baseline reports suggest that there was some activity in this area at baseline, with between a quarter and a third of Challenges participants having applied for IP at baseline.** More broadly, the UK demonstrated strong patenting activity in the following Challenge areas at baseline: Data to Early Diagnosis and Precision Medicine, Medicines Manufacturing, Robotics for a Safer World, Quantum Technologies and Faraday Battery.
- **For Challenges for which we were able conduct bibliometric analysis, the performance at baseline was strong, with normalised citation impacts and proportion of highly cited publications well above world average.** In-depth bibliometric analysis within specific Challenge areas highlights that the UK was among world leaders in fields relating to the Robotics for a Safer World, Industrial Decarbonisation, Faraday Battery and Quantum Technologies at baseline. At the same time, there were some Challenge areas in which publications output was low, or where publications were not a focus.
- **Evidence from Challenge-level baselining and Fund-level baselining workshops suggests that there were consistent obstacles preventing the adoption of new technologies and innovations at scale at baseline, including:**
    - **Issues around policy regulation and standards** – such as lack of pressure from policy on renewable packaging or lack of standards and certification for robotics technologies. Common barriers posed by the existing policy landscape at baseline are summarised in Figure 1.
    - **Challenges in existing business models** – such as incompatibility between Smart Local Energy Systems (SLES) and existing supply-focused business models. However, we also noted that for some Challenges (e.g. Audience of the Future and Next Generation Services) there had already been experimentation with new business models at baseline.
    - **Limited awareness of key stakeholders** – there was general awareness of R&I opportunities within the Challenge areas among policymakers at baseline. However, in many cases, awareness of the specific needs of the Challenges was low, with significant gaps

in policymakers' understanding and engagement. For example, while there was good awareness of the economic contribution of the creative sector to the UK, the role of R&I within the creative industries was not well understood by policymakers, resulting in limited funding to support R&I.

- **High costs and lack of investment** – for example lack of funding for capital infrastructure investments in the NHS, or lack of investment in R&I in some sectors such as the creative sector.
- **Barriers around data access and security** – for example, lack of effective data-sharing mechanisms to support distributed energy assets, or challenges obtaining data access needed to support AI technologies in health.
- **Fragmentation of the sector** – awareness of businesses regarding R&I opportunities within the Challenge areas was varied at baseline, with some baseline surveys (e.g. in services and farming sector) demonstrating good levels of interest among businesses in Challenge-relevant technologies and innovations, whilst others found low levels of engagement and understanding (e.g. low understanding in businesses of carbon capture, utilisation and storage, or a long-standing disconnect between academic research and industrial innovation in the battery sector).
- **Lack of training or skills** – for example, lack of digital skills as a barrier to adoption of precision agriculture techniques, or lack of technical AI skills within companies.
- **Lack of infrastructure** – for example barriers faced by businesses to accessing research facilities and constraints on infrastructure within the healthcare system.

Figure 1: Common barriers posed by existing policy landscapes at baseline



Capacity and investment: The ISCF aims to increase capacity and investment in R&I in the UK. In addition to public investment, this means ensuring generation of wider private and overseas funding towards addressing the Challenges and ensuring the skills and physical infrastructure are in place to enable, encourage and capitalise upon that investment. In turn, the Fund aims to contribute to employment and new business creation within the Challenge areas, paving the way for longer-term economic impact. In this area, we identify the following baseline findings:

- **At baseline, ISCF participant businesses had some experience funding and delivering R&D projects but there was considerable variation across Challenges, reflecting broader variation in levels of R&D across sectors.** In the Faraday Battery and Medicines Manufacturing Challenges, for example, participant organisations typically had numerous R&D investment projects at baseline. In the Next Generation Services Challenge, meanwhile, more than half of participant businesses invested less than £50,000 overall in AI and data applications R&D at baseline. In some Challenge areas, such as Industrial Decarbonisation and Future Flight, business R&D expenditure was concentrated within a small number of high-performing and/or well-established firms.
- **There was evidence of overseas investment in UK R&D across many sectors,** and foreign direct investment in R&D (totalling £5.06bn in the UK in 2018, of which £3.25bn was spent in businesses) was particularly important within certain Challenge-relevant sectors, including the life sciences sector and the chemicals, ceramics and metals sectors.
- **Wider investment in UK R&D and UK businesses varied considerably between sectors.** There was also public sector funding, which was important in some areas, notably aerospace and quantum

technologies, but less well-established in sectors relevant to other Challenges (e.g. Next Generation Services and Audience of the Future). The third sector played an important role in funding medical R&D.

- **Private sector investment in UK businesses also varied.** For example, within the services sector, the insurance industry alone raised £65.bn in private investment in 2017/18; while for the entire creative services sector, £291m was raised between 2017 and 2020.
- **Investment in R&I across several sectors was considered high-risk,** with inadequate mechanisms to support investment, adoption and scale-up (e.g. Low Cost Nuclear and Digital Security by Design).
- **Several sectors faced difficulties sourcing the right type of skills at baseline,** specifically individuals with experience around innovation adoption and uptake. In general, sectors lacked a programme of investment in skills. While some sectors relied on international, in particular European, talent, this has declined since the UK's exit from the European Union (EU). At baseline, most IUK projects reported contributions to the development of new skills or the improvement of existing ones.
- **There were gaps in R&I infrastructure and need for further investment.** For some sectors, infrastructure to support R&I was mostly missing. In others, there was some existing R&I infrastructure, but this lacked coordination, and did not support scale-up and adoption.
- **Across most sectors, equality, diversity and inclusion in the workforce was emerging as a topic, with pockets of activity often concentrated in larger firms.** However, overall activity was limited and often focused on some aspects of diversity (e.g. gender) rather than a holistic picture of diversity and inclusion across a range of dimensions.
- **There was a general trend of increasing employment in R&D**, with most UK R&D workers employed in higher education and engineering professions, and within the public sector and the manufacturing sector. With respect to employment more generally, there was considerable business and job creation in some sectors and sub-sectors, with several others at a turning point. Across a number of Challenge areas, a strong unmet demand for employment was noted.

Connected innovation ecosystem: The fostering of multi-sectoral, multidisciplinary and multi-stakeholder collaborations and networks is a core aim of the ISCF. A connected innovation ecosystem is necessary for the development of innovative solutions but also to ensure that the wider environment for adoption and improvement is in place. Through collaborative funding, as well as wider activities, ISCF funding aims to bringing together coalitions of stakeholders to drive the Challenges forward. Linked to this, the Fund seeks to contribute to international recognition of the UK as a leader within the Challenge areas. In this area, we identify the following baseline findings:

- **Based on the evidence available, at baseline, most participants in the ISCF across Challenges had some prior experience of business-business collaboration.** For example, at baseline, 58 per cent of participants in the Quantum Technologies Challenge had collaborated with other businesses. Similarly, for the Transforming Construction Challenge, 81 per cent of survey

respondents from industry had collaborated with other construction businesses in the year prior to TCC engagement.

- **There was variability in presence of business-academic collaborations at baseline, with low levels of collaboration in some areas.** For example, for the Data to Early Diagnosis Challenge, 83 per cent of respondents to a baseline survey of precision medicine firms reported collaborations with universities or other higher education institutions. Similarly, 81 per cent of respondents for the Transforming Construction Challenge reported that they had collaborated with academic/research organisations in the year prior to engagement in the Challenge. By contrast, for the Next Generation Services Challenge, only around a third of organisations reported the involvement of an academic partner in prior R&D projects.
- **The level of multidisciplinarity at baseline is comparable to IUK and UKRI averages,** based on scientometric analysis of baseline publications of ISCF award holders.
- **Academic institutions in the UK are broadly considered to have world-class expertise in a range of areas relevant to Challenges.** However, this recognition is not always reflected in industry reputation, where the picture is more mixed and its strength reliant on a small number of key players.
- **Network analysis of event attendance data suggests a rich pattern of connectivity and engagement across the ISCF Challenges, with no obvious silos within the network.** Event data also suggests that ISCF Challenges can be grouped into five 'communities'. Generally these groupings are quite intuitive given the subject areas of the Challenges. For example, three Challenges with an explicit focus on decarbonisation (Transforming Construction, Prospering from the Energy Revolution and Industrial Decarbonisation) are grouped, as are a number of Challenges with a clear focus on the manufacturing sectors. However, some connections are perhaps more surprising, such as the link between Healthy Ageing and Audience of the Future.
- **By comparison, network analysis of project collaboration data suggests a more sparsely connected network comprised of fewer organisations and with some siloes.** Large organisations are not significantly better connected than smaller organisations but may play an important bridging role within the network. Project collaboration data also suggest different communities to those based on event attendance data, reflecting the different nature of project-based collaboration.

Economic impact: Through the creation of knowledge and innovation pathways, enhanced capacity and investment, and the establishment of a connected innovation ecosystem, the ISCF aims to deliver long-term economic impacts for the UK. This includes the growth of UK businesses and expansion into new markets and sectors, increased gross value added (GVA) and productivity, and increased spread of economic benefits across UK regions. In this area, we identify the following baseline findings:

- **The ISCF supports a wide variety of UK businesses working in sectors with very different characteristics.** Some businesses were working in large, well-developed sectors already on the rise at baseline, while others were smaller and less well-established. For example, in 2016, the legal services sector alone generated a total revenue of £35.4bn, while companies in the aviation and aerospace sectors had a collective turnover of nearly £85bn at baseline. Smaller, emerging sectors,

such as the creative immersive sector associated with Audience of the Future, had much lower turnover; indeed, at baseline, two fifths of ISCF-funded businesses derived no turnover from immersive content or technologies.

- With some exceptions (notably Industrial Decarbonisation and Transforming Construction), **the GVA and productivity of Challenge-relevant sectors were largely increasing at baseline,** in line with wider trends for UK GVA growth.
- **From the limited evidence available, most Challenge-relevant businesses were concentrated in London and the South East.** For example, the biggest proportion of precision medicine companies are based in London (22.7 per cent) followed by the South East (20.7 per cent). Similarly, London and the South East dominate the quantum technology sector with 23 per cent and 21 per cent of relevant businesses based there respectively. The regional skew is even more pronounced in the creative immersive sector, where the London workforce accounts for almost 46 per cent of the total workforce. This is in line with the broader distribution of all UK businesses at baseline, with London and the South East accounting for 35 per cent of the UK business population in 2018, and with trends in the geographical distribution of R&D investment in the UK.

Societal Impact: In addition to long-term economic impact, the ISCF also aims to contribute to a wider range of societal impacts, including impacts on health and wellbeing, and the environment and sustainability. In this area, we identify the following findings:

- At baseline, **data on health indicated static or declining performance across several key metrics** including life expectancy, inequality and healthcare costs.
- **Environmental and sustainability issues were already on the agenda – and resonating with the public – but progress had been mixed, with greenhouse gas (GHG) emissions still relatively flat.** By design, ISCF Challenges target some of the key sectors identified as having high emissions at baseline – notably manufacturing, transport and energy.

As well as helping to establish the Fund-level picture at baseline, we also used baselining workshops to discuss wider factors, trends and interventions occurring in parallel to the ISCF that could contribute towards (or indeed inhibit) the aims of the Challenges and the Fund overall. This will require ongoing monitoring and review over the course of the evaluation, but an initial assessment at the outset allows us to be alive to known trends and interventions from the start of our work. We identified both internal barriers, due to UKRI and Innovate UK (IUK) processes, and wider contextual barriers or facilitators to the Fund's progress. Internally, participants in the workshops identified that some aspects of the ISCF's design and implementation have limited the Fund's ability to deliver the intended impact in the Challenge areas. These include the agility and flexibility of the Challenges, the scale and timeline of funding relative to the scale of the Challenges, and management structures within UKRI. Taking a broader perspective, we identify a range of wider factors that can support or inhibit the progress of the ISCF towards its intended goals which can be broadly clustered into four themes:

- **Regulatory and policy environment:** Technological innovation is unlikely to be adopted where there are significant regulatory barriers. Equally, a supportive policy environment can drive significant industry and wider engagement towards implementation.

- **Public acceptability and ethical issues:** These were chiefly raised in relation to health-focused Challenges. but could also prove to be an issue in other areas where novel technologies require public acceptance to be implemented.
- **Network of engagement across sectors:** Across all sectors, the engagement of key stakeholders was identified as an important factor that can influence the extent to which Challenges will be able to deliver on their objectives. Key groups identified include policymakers, users and the investor community. The value of existing networks and focal points for different areas was highlighted.
- **Exogenous shocks:** Key examples raised include the UK's departure from the EU and the Covid-19 pandemic. The effects of these are mixed and vary across Challenges – often providing both opportunities and difficulties in different ways.

Broadly, the baseline situation in relation to the Fund reflects the purposes for which the Challenges were established. In most cases, Challenges were intended to address market failures such as fragmentation of a sector and a lack of a focal point to drive efforts in a specific area; the need for collective action to radically rethink underlying technology in a sector; or the need for a significant shift in regulation or prevalent business models to enable progress. The specific aims of the Challenges are reflected in the conditions at baseline and therefore the Fund-level picture is correspondingly mixed. However, we can identify some themes that broadly apply across contexts, in particular a lack of connections and interactions between key stakeholders (whether between businesses, or with policymakers or other stakeholders); a need for additional, or more often, specifically targeted investment to address a key challenge or issue; the lack of a focal point around which a sector or field can coalesce; and a strong academic base which had not always been translated to achieve its full innovative and economic potential.

This baseline assessment has several implications for the next steps in the evaluation. Firstly, this variability means it is difficult to provide a quantitative assessment for indicators at this baseline point, and this is likely to be equally challenging at the Fund level for the overall impact evaluation. In addition, we will need to continue to monitor wider trends and factors that may influence the progress of the Fund from baseline over the course of the evaluation, building on this initial assessment, as these will continue to emerge and evolve. These observations point to the planned contribution of an analysis-based approach being well-placed to assess the available evidence and provide a meaningful evaluation of the Fund's achievements.

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Abbreviations

AI	Artificial Intelligence
BEIS	Department for Business, Energy and Industrial Strategy
BHF	British Heart Foundation
CCUS	Carbon Capture, Utilisation and Storage
CNCI	Category Normalised Citation Impact
CR&D	Collaborative Research and Development
DHTC	Digital Health Technology Catalyst
DWPI	Derwent World Patents Index
EDI	Equality, Diversity and Inclusion
ERIS	Energy Revolution Integration Service
FDI	Foreign Direct Investment
FTE	Full-time Equivalent
FWCI	Field-weighted Citation Impact
GVA	Gross Value Added
HCP	Highly Cited Publications
IP	Intellectual Property
ISCF	Industrial Strategy Challenge Fund
IT	Information Technology
ITT	Invitation to Tender
IUK	Innovate UK
KTN	Knowledge Transfer Network
NAO	National Audit Office
NHS	National Health Service
NIPF	National Industrial Productivity Fund

NUTS	Nomenclature of Territorial Units for Statistics
ONS	Office for National Statistics
PCF	Project close-out form
R&I	Research and Innovation
R&D	Research and Development
RFI	Request for Information
SLES	Smart Local Energy System
ToC	Theory of Change
TRL	Technology Readiness Levels
UKRI	UK Research and Innovation

1. Introduction

This report sets out the baseline for the Fund-level evaluation of the Industrial Strategy Challenge Fund (ISCF). The report has been prepared as the deliverable of 'phase 2 of the evaluation plan, as specified in the Invitation to Tender (ITT).

The report is structured as follows:

- The remainder of this introduction provides an overview of the ISCF, the aims of the Fund-level evaluation, and the overarching evaluation framework
- Chapter 2 presents the aims of the baseline measurement phase and describes the research methods used to develop the Fund-level baseline
- Chapters 3–7 are structured around the key evaluation themes to present the baseline findings
- Chapter 8 considers barriers, enablers and trends that may impact on the implementation of the ISCF, as highlighted by the baseline findings
- Chapter 9 presents key conclusions of the baseline analysis and implications for the remaining phases of the evaluation

The annexes of the report present additional supplementary information. Alongside materials related to the preparation of this baseline report, the annexes also include the outcome of scoping work undertaken to inform later phases of the evaluation. This includes implications of the preliminary network analysis (conducted to inform this baselining report) for the final network analysis to be conducted as part of the impact evaluation (Annex C), and further scoping of the econometric analysis also to be conducted as part of the impact evaluation (Annex D).

1.1. The Industrial Strategy Challenge Fund (ISCF)

Delivered by UK Research and Innovation (UKRI), the ISCF supports the development of solutions to major industrial and societal challenges facing the UK through the delivery of a mission-oriented research and innovation (R&I) funding programme with a total commitment of £2.6bn from the UK government's National Productivity Investment Fund (NPIF), combined with an additional £2.83bn in co-investment. Under the ISCF's mission-oriented approach, funding has been distributed through the creation of individual 'Challenges', each focusing on a pressing industrial and societal issue, with business and academic partners invited to bid collaboratively for projects that have the potential to contribute to addressing each Challenge. Thus far, 20 such Challenges have been established. The ISCF portfolio also includes four

programmes (as well as wider investments) not established through the Challenge approach.[1] An overview of the ISCF Challenges and programmes is presented in Table 1 below.

Table 1: Overview of ISCF Challenges and programmes

ISCF Challenge or programme	Key aims
Challenges	
Wave 1b	
Faraday Battery	The Faraday Battery Challenge aims to drive the growth of a strong battery business in the UK through the development of battery technologies that are cost-effective, high-performing, longer-range, faster-charging, long-lasting, safe and recyclable.
Medicines Manufacturing	The Medicines Manufacturing Challenge aims to promote the UK as a world leader in medicines manufacturing and the delivery of novel treatments. As part of the Challenge, the Digital Health Technology Catalyst (DHTC) programme supports R&D projects aiming to accelerate the development and commercialisation of digital health technologies.
Robotics for a Safer World	The Robotics for a Safer World Challenge supports the development of novel robotics and AI technologies and systems to reduce the number of people working directly in extreme environments.
Wave 2	
Audience of the Future	The Audience of the Future Challenge supports the development of immersive experiences and technologies in the UK-based creative sector, including research to better understand audiences for immersive productions.
Data to Early Diagnosis and Precision Medicine	The Data to Early Diagnosis and Precision Medicine Challenge supports the development of precision medicine for improved early diagnosis and treatment and accelerate the use of research and health data.
Healthy Ageing	The Healthy Ageing Challenge aims to enable businesses, including social enterprises, to develop and deliver scaled-up products, services and business models to support people as they age.
Next Generation Services	The Next Generation Services Challenge supports the UK's service industries to use technologies such as artificial intelligence (AI) and data analytics to develop the next generation of services.
Prospering from the Energy Revolution	The Prospering from the Energy Revolution Challenge aims to accelerate innovation in smart local energy systems.
Quantum Technologies[2]	Building on the UK's National Quantum Technology Programme, the Quantum Technologies Challenge supports new products and technologies based on advances in quantum science.
Transforming Construction	The Transforming Construction Challenge aims to accelerate a shift in the construction sector towards manufacturing and digital processes and a value outcome approach.
Transforming Food Production	The Transforming Food Production Challenge supports the development and adoption of new ways to produce food with a view to improving the productivity and resilience of primary food production while also reducing emissions and pollution.
Wave 3	

[1] The non-Challenge elements of include investments made under Wave 1a of the ISCF, including the Creative Industries Clusters Programme and the following Wave 1b programmes: Self Driving Vehicles, National Satellite Test Facility and Next Generation Aero Materials.

[2] Following on from the Quantum Technologies Challenge, the Commercialising Quantum Technologies Challenge was established in Wave 3.

Accelerating Detection of Disease	The Accelerating Detection of Disease Challenge supports research into the early diagnosis, prevention and treatment of chronic disorders using biological and digital data from up to 5 m volunteers.
Digital Security by Design	The Digital Security by Design Challenge supports projects that help the UK digital computing infrastructure to become more secure.
Driving the Electric Revolution	The Driving the Electric Revolution Challenge supports the UK's push towards a net-zero carbon economy and clean technology supply chains through investment in electrification technologies including power electronics, electric machines and drives.
Future Flight	The Future Flight Challenge aims to bring together technologies in electrification, aviation systems and autonomy to create new modes of air travel and capability, including all-electric aircraft and deliveries by drone.
Industrial Decarbonisation	The Industrial Decarbonisation Challenge aims to contribute to the UK's drive for clean growth across heavy and energy intensive industries through development and deployment of technologies such as carbon capture, utilisation and storage and hydrogen fuel switching.
Low Cost Nuclear	The Low Cost Nuclear Challenge aims to develop a compact, standardised nuclear power station product based around a UK-designed Small Modular Reactor (SMR).
Smart Sustainable Plastic Packaging	The Smart Sustainable Plastic Packaging Challenge aims to tackle the challenge of plastic pollution in the environment by facilitating the development of a more sustainable plastic packaging value chain.
Manufacturing Made Smarter	The Manufacturing Made Smarter Challenge aims to help the UK's manufacturing industry become more productive and competitive through innovation and the adoption of digital technologies.
Transforming Foundation Industries	The Transforming Foundation Industries Challenge supports the development of innovative technologies, collaborations and investment in the foundation industries in order to increase competitiveness and reduce environmental impact. The six relevant sectors are as follows: cement, glass, ceramics, paper, metals and chemicals.
Non-Challenge programmes	
Creative Industries Clusters	The Creative Industries Clusters programme supports growth and technological innovation within the creative economy through investment in clusters of creative R&D across the UK.
Self Driving Vehicles	The Self Driving Vehicles programme aims to develop next-generation AI and control systems for driverless cars.
National Satellite Test Facility	The National Satellite Test Facility programme aims to support the assembly, integration and testing of space payloads and satellites.
Next Generation Aero Materials	The Next Generation Aero Materials programme aims is to develop the next generation of affordable light-weight composite materials for aerospace, automotive and other advanced manufacturing sectors.

Across all 24 Challenges and programmes, the ISCF has five cross-cutting objectives. These are to:

- Increase UK businesses' investment in R&D and improve R&D capability and capacity
- Increase multidisciplinary and inter-disciplinary research around the Challenge areas
- Increase business-academic engagement on activities relating to the Challenge areas
- Increase collaboration between younger, smaller companies and larger, more established companies within the value chain
- Increase overseas investment in R&D within the UK

By pursuing these objectives, all Challenges and programmes aim to contribute not just to the advancement of new knowledge and technological solutions, but also to the advancement of cross-sector investment, capacities, networks and collaborations within the relevant areas.

Since its establishment in 2018, the ISCF has adapted to a changing UK policy landscape. The UK government, for example, has sought to adapt the ISCF to contribute to its 'levelling up' agenda, addressing regional disparities in economic and social outcomes, and to also contribute to its aim to achieve net-zero carbon emissions by 2050. While initially linked directly to the 2016 UK Industrial Strategy and the associated Grand Challenges, the overarching strategic framework surrounding the ISCF has been altered significantly by the termination of the Industrial Strategy, announced in February 2021, and its replacement by a new post-Covid-19 'Plan for Growth'. Together with the new UK Innovation Strategy published in July 2021, these changes could bring changes to the overarching objectives of the ISCF and, potentially, what it is expected to deliver. It is also possible that further adaptations will be made to the ISCF as a result of a National Audit Office (NAO) report on UKRI's management of the Industrial Strategy Challenge Fund published in February 2021,[3] and a report of the House of Commons Public Accounts Committee (PAC) published in April 2021.[4]

1.2. Evaluation aims and structure

RAND Europe and Frontier Economics have been commissioned by UKRI to undertake a Fund-level evaluation of the ISCF. The aim of this evaluation is to build an evidence base with which to judge the success and overall impact of the ISCF in order to:

- Inform ongoing and future improvements to the ISCF to maximise the value of public funding
- Demonstrate the return on investment to taxpayers
- Build the evidence base on the impact of mission-oriented and challenge-focused R&I support as part of UKRI's wider efforts to understand 'what works' in R&I policy and delivery

Alongside this evaluation, UKRI is also commissioning evaluations of each of the ISCF Challenges. The Challenges are each being evaluated by independent evaluators, with interim and final evaluation reports for each Challenge to be delivered over the course of the Fund-level evaluation.[5] This Fund-level evaluation seeks to complement these Challenge-level evaluations by focusing on what the Fund as a whole has delivered. While drawing upon the findings and data collected in the Challenge-level evaluations, the Fund-level evaluation will also seek to collect new data in order to understand the overall impact of the ISCF, as well as to consider the overall contribution of the Challenge-led approach. The Fund-level evaluation will be implemented through four overarching phases: evaluation framework development (phase 1, completed); baseline measurement (phase 2, culminating in this report); review of Challenge-level evaluation findings

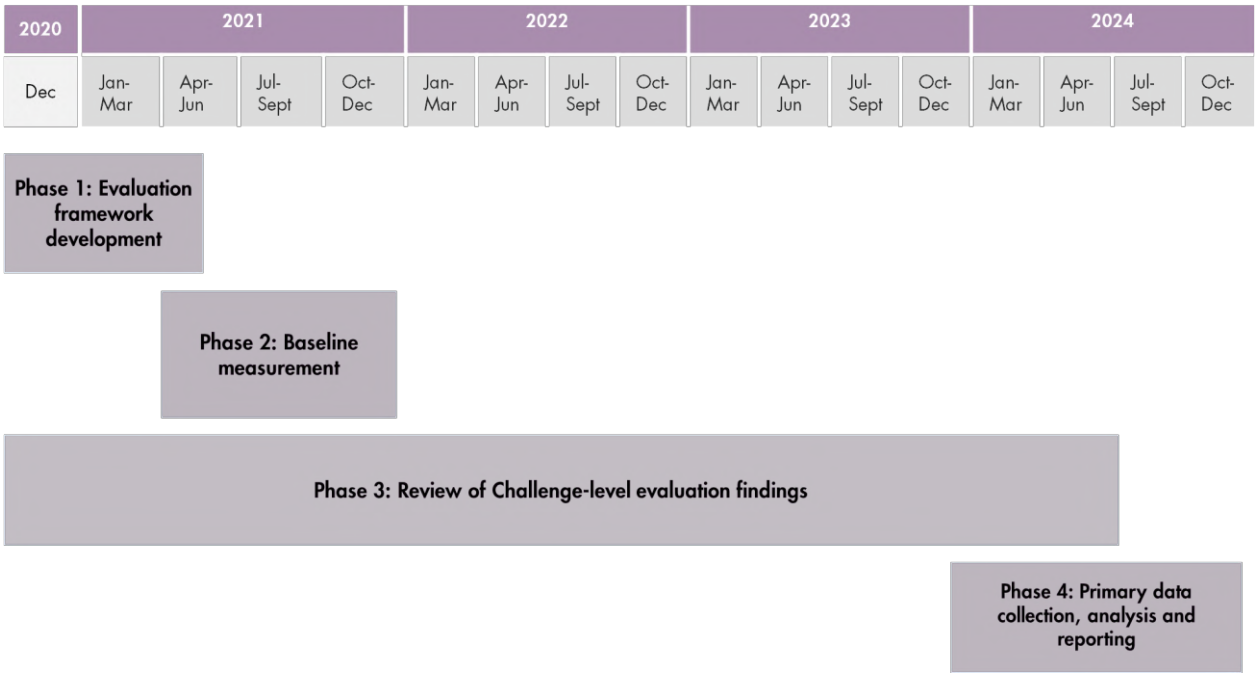
[3] National Audit Office, 'UK Research and Innovation's Management of the Industrial Strategy Challenge Fund,' February 3, 2021.

[4] House of Commons Committee of Public Accounts, 'Industrial Strategy Challenge Fund: Fifty-Sixth Report of Session 2019–21,' April 22, 2021.

[5] The non-Challenge ISCF programmes are not being evaluated in the same way.

(phase 3, in progress); and primary data collection, analysis and reporting (phase 4, to be completed). The evaluation phases and timeframes are visualised in Figure 2 below.

Figure 2: Evaluation implementation stages and timeframes



1.3. ISCF Theory of Change and evaluation framework

The foundation for this Fund-level evaluation is an ISCF Theory of Change (ToC). The ToC, developed collaboratively with UKRI during the evaluation framework development phase, provides a description of how the ISCF is expected to achieve its aims through a logic model approach identifying key 'inputs', 'activities', 'outputs', 'outcomes' and longer-term 'impacts' expected to result from the Fund. Over the course of the evaluation, data and evidence will be collected to examine the extent to which the ISCF has achieved the anticipated outputs, outcomes and impacts. A visual representation of the ISCF ToC is provided in Figure 3 below. A more detailed guide to the ToC has been presented in the evaluation framework report.

In outlining intended outputs, outcomes and impacts of the ISCF, the ToC is structured these around five evaluation themes. Intended outputs and outcomes of the ISCF are structured around three evaluation themes related to the intended change mechanisms of the Fund. The three themes are as follows:

- **Creating knowledge and innovation pathways:** This theme will consider the contribution of the ISCF to the development of new knowledge addressing the Challenges, and the promotion, advancement, and adoption of new innovations. It will also consider the contribution of the ISCF to stakeholder awareness and evidence-based policy surrounding the Challenges.
- **Capacity and investment:** This theme will consider the extent to which the ISCF has helped to increase capacity and investment in R&I in the UK. This will include the role of the ISCF in

leveraging private and public investment towards addressing the Challenges, and its contribution to skills, infrastructure, employment and new business creation within the Challenge areas.

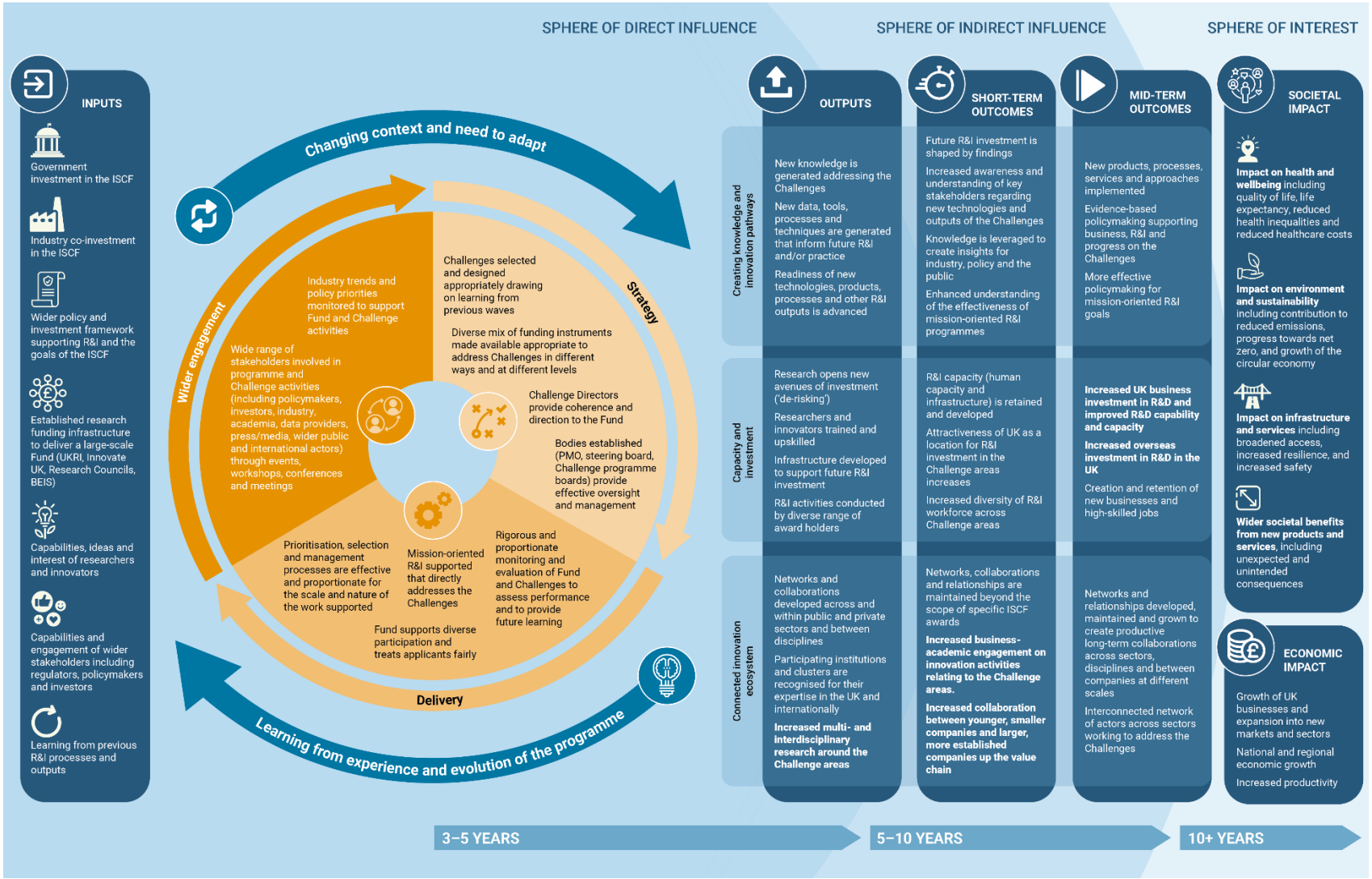
- **Connected innovation ecosystem:** This theme will consider the extent to which the ISCF has helped to foster multidisciplinary, interdisciplinary, multi-sectoral and multi-stakeholder collaboration and networks around the Challenges, as well as the contribution of the ISCF to international recognition of the UK as a leader within the Challenge areas.

Intended impacts of the ISCF are structured around two key evaluation themes as follows:

- **Economic impact:** This theme considers the extent to which the ISCF has delivered substantive, long-term impacts for the economy, including the growth of UK businesses (including in international markets), national and regional economic growth, and increased productivity.
- **Societal impact:** This theme considers the extent to which the ISCF has delivered substantial long-term impacts for society, focusing on benefits to health and wellbeing, the environment and sustainability, and infrastructure and services. It also considers the contribution of the ISCF to wider societal impacts, including unanticipated impacts.

For each of these five themes, the evaluation framework identifies evaluation questions, indicators and data collection mechanisms that will be used to assess the contribution of the ISCF.

Figure 3: ISCF Theory of Change



2. Baseline measurement – aims and approach

2.1. Aims of the baseline measurement phase

The aim of the baseline measurement phase of the evaluation is to review quantitative and qualitative data on the state of the UK R&I landscape in sectors relevant to the ISCF Challenges at the time of establishment of the ISCF. The baselining phase also aims to consider contextual factors that might impact upon the success of the ISCF, including potential barriers to, and enablers of, its implementation and delivery. The baselining phase will help to inform the impact evaluation of the ISCF – to be undertaken in phases three and four of the evaluation – by allowing us to compare the achievements of the Fund to what was already in existence previously.[6]

The baseline measurement phase builds upon the ToC and evaluation framework developed during the first phase of this evaluation. As noted above (see Section 1.3), in outlining intended outputs, outcomes and impacts of the ISCF, the ToC is structured around five evaluation themes:

- Creating knowledge and innovation pathways
- Capacity and investment
- Connected innovation ecosystem
- Economic impact
- Societal impact

For each theme, the evaluation will collect data to assess the contribution of the ISCF in relation to specific evaluation questions and indicators. To meaningfully assess the contribution of the ISCF across these themes, however, it is first necessary to understand the baseline position of the UK R&I landscape within each thematic area, against which the future contribution of the Fund can be compared.

Another aim of the baselining phase is conduct scoping work to inform future phases of the evaluation. Specifically, we have conducted further scoping to inform the network analysis and econometric analysis

[6] Alongside the baselining conducted for this report, the evaluation will also employ other approaches intended to understand the 'counterfactual' for the ISCF. When analysing the economic impact of the Fund, this will include the use of a counterfactual set of businesses that did not participate in the ISCF to assess comparative performance over time. We also propose to compare aspects of the ISCF's performance against a comparator set of non-ISCF IUK awards. More information on the proposed approach to measuring economic measuring impact of the Fund is presented in Annex D of this report.

components of the impact evaluation. The outcomes of this scoping are presented in Annex C and Annex D respectively.

2.2. Baselining methodologies

Our baselining approach consists of four main methodologies, as set out below.

2.2.1. Review of Challenge-level baseline reports

To inform our baseline measurement, we reviewed baseline reports submitted as part of the evaluations of individual ISCF Challenges. At the time of completing this baseline report, we had received 17 Challenge-level baseline reports from UKRI. The baseline reports reviewed are listed in Annex A.

The review of Challenge-level baseline reports used the qualitative data analysis software MaxQDA to code Challenge-level baseline findings against the Fund-level evaluation framework. For each aspect of the evaluation framework, coded data was then analysed to draw out Fund-level baseline insights, including through triangulation with data collected through other methods. The data collected through the review of Challenge-level reports also helped to inform and refine our approach to other data collection methods, in particular the baselining workshops described further below.

There were four Challenges (Health Ageing, Accelerating Detection of Disease, Driving the Electric Revolution, Manufacturing Made Smarter) for which a baseline report had not been received at the time of completing this report. In addition, baseline reports are not being submitted for three of the non-Challenge ISCF programmes (Self Driving Vehicles, National Satellite Test Facility, Next Generation Aero Materials). As noted below (Section 2.3), where Challenge-level baseline reports are to be published in the future, findings from those reports will be incorporated into this report via the addition of an addendum, to be produced once all remaining reports are available. For those non-Challenge programmes that will not produce baseline reports, baseline data has been reviewed and incorporated into this report using market analysis reports prepared for UKRI during the design phase of each programme.[7] While not providing a comprehensive source of baseline data, these market analysis documents have helped to build an understanding of some features of the landscape within relevant sectors prior to the establishment of ISCF programmes.

2.2.2. Secondary data source review

Alongside the review of Challenge-level baseline reports, we also reviewed secondary data sources. The aim of this was to identify data that could help to provide broad quantitative measures relevant to indicators used in the evaluation. The task broadly consisted of two main tasks: (i) analysis of centrally held IUK data and (ii) analysis of wider secondary data.

[7] At the time of submitting this baseline report, market analysis reports had been shared for the Self Driving Vehicles and Next Generation Aero Materials programmes.

IUK centrally held data

Centrally held IUK data was used to consider the baseline performance of the wider IUK portfolio in areas of relevance to the evaluation framework. The data shared by IUK comprised treated and cleaned project close-out form (PCF) data from all IUK projects (including ISCF projects) initiated between 2018 and 2021. For the purposes of baselining the wider IUK portfolio, ISCF projects were removed from the analysis such that the analysis did not reflect the impact of ISCF. Types of data used to inform our baseline analysis include: the number of publications per project, the stage of projects with respect to protecting intellectual property (IP), the number of projects reporting contributions to skills development, the number of projects with plans to produce academic and wider commercial spin-outs.

Wider secondary data

Wider secondary data was used to inform a picture of the national landscape regarding UK R&I prior to the launch of the ISCF. The data reviewed included: Scopus and Dimensions data on publication outputs; UK Innovation Survey data on measures of 'innovation activity'; Office for National Statistics (ONS) data on R&D investment of UK businesses, overseas investment in the UK and R&D roles in UK businesses by country and region; and Labour Force Survey data on the R&D workforce. ONS data was also used to provide baseline measures for areas of long-term anticipated societal impacts of the ISCF, including life expectancy, healthcare costs, proportion of energy from renewables, proportion of waste recycled, and greenhouse gas emissions.

2.2.3. Baselining workshops

To further develop our baseline measurement, we conducted five baselining workshops. The aim of these workshops was to explore qualitatively the baseline UK R&I landscape within broadly defined sectors relating to the ISCF Challenges, while also considering contextual factors that may impact on the implementation of the ISCF within each sector. The sectoral focus of the workshops was designed to enable common discussion of the context and landscape prior to the ISCF within different areas of the R&I ecosystem.

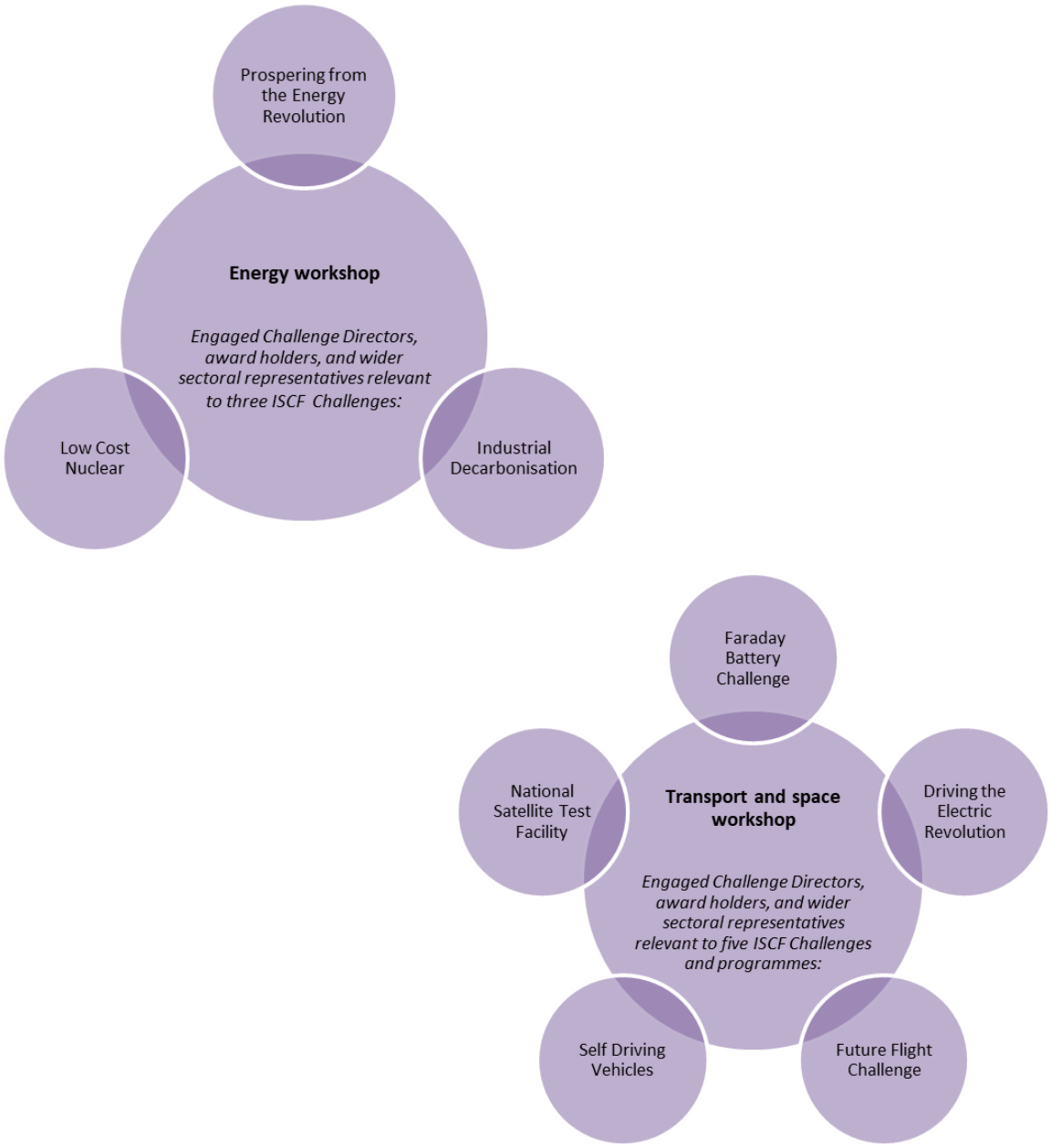
Each baselining workshop was attended by:

- Challenge Directors of ISCF Challenges relevant to the sectoral theme
- A sample of ISCF award holders from ISCF Challenges relevant to the sectoral theme
- Representatives from wider sectoral bodies (including government departments) with expert knowledge of the sector and/or the relevant Challenge areas

For each workshop, the inclusion of wider sectoral representatives not affiliated with ISCF Challenges was considered important to ensure 'external' perspectives on the baseline position of the UK R&I landscape, alongside the 'internal' perspective offered by Challenge Directors and award holders. The average number of participants per workshop was 12. All workshops were conducted virtually using Microsoft Teams and each lasted 3.5 hours. The structure of the baselining workshops is illustrated by Figure 4 below. Further information on the topics covered by the workshops can be found in Annex B. Throughout the report we have included evidence from the different workshops. Information has only been included in this report if

we consider it to be a key observation or finding from that workshop, i.e. it was a point agreed upon by several participants.

Figure 4: Structure of the baselining workshops



2.2.4. Network analysis

As part of the baselining phase, we also undertook a preliminary network analysis. The network analysis explores the connections between different ISCF Challenges and between the organisations engaging with the Challenges in different ways (events and funded projects). The analysis provides initial insights into the relationships between ISCF Challenges and the nature of collaboration across ISCF projects. We anticipate that it will be beneficial to conduct a similar analysis as part of the final impact evaluation, once the Challenges are more developed (or, in some cases, complete) and more data is available on collaboration. In this sense, the initial network analysis can be viewed as helping to establish a baseline for the final network analysis to be conducted at a later stage, as well as a 'proof of concept' in the (relatively novel) use of network analysis to support programme evaluation in this way. However, it should be noted that this analysis is not strictly a 'baseline' in the sense used elsewhere in this report. This is because the analysis is based on the early outputs of the ISCF, rather than data on the state of collaboration at the point that ISCF was

established (which is evidenced through other forms of data in this baseline report). It does, however, provide a point of comparison for the later evaluation.

The initial network analysis examined two sources of data on the connections between ISCF organisations and Challenges: (i) Knowledge Transfer Network (KTN) data on events organised by Challenges and attended by organisations and (ii) Delphi, an internal UKRI dataset recording details of funded projects. As explained in Chapter 5, both the KTN and Delphi data were analysed in two ways: as a network of organisations and as a network of Challenges.

KTN event data

KTN data provided an anonymised list of attendees for ISCF events. This covers a broad range of types of event, including briefings, webinars, workshops and networking events. For each attendee, the data contained the name of the organisation they belonged to and the organisation 'type' (for example, University or R&D Active Business).[8] The data accessed contained information on 260 events held between August 2017 and July 2021, attended by 4,424 distinct organisations.

We assigned each event to an ISCF Challenge based on its name. In most cases this was straightforward (for example, the event name included the Challenge name). However, some events could not be easily assigned. Where we could not confidently assign an event to a Challenge, we did not include the event in the analysis.[9]

KTN data helped to identify connections between organisations and Challenges in terms of their overlapping subject areas, commercial interests and ISCF engagement, and provided insights into the structure of ISCF participation across Challenges. At the same time, mutual event attendance does not necessarily imply a collaborative link between organisations.

Delphi project data

Delphi data provided a list of organisations, the projects they are involved with, the grant funding they have received for each project and the Challenge that the project is associated with. The Delphi data also provided some information on the type and size of organisations (for example, academic or business and small, medium or large).

Delphi data helped to capture formal collaborative links between organisations on ISCF projects. However, it does not necessarily reflect other, possibly informal, collaborative links between organisations. Additionally, the results will depend to some extent on the number of project grants awarded for each Challenge to date. The benefits and drawbacks of using KTN data and Delphi data as the basis for network analysis are discussed further in Chapter 5.

[8] Event attendees from UKRI and IUK were excluded from the data.

[9] Of the 260 events, we were unable to assign a Challenge in 45 cases (17%). For two ISCF programmes, Next Generation Aero Materials and Self Driving Vehicles, we did not identify any events. As part of the final evaluation, we suggest conducting a more intense manual exercise and validation with the Challenges and ISCF to increase this match rate. If a significant group of events cannot be allocated we can, as a sensitivity, include an 'unallocated' group in the network analysis.

2.3. Other baseline data to be collected

The analysis presented in this report represents an important step in understanding the baseline picture of the ISCF to compare later assessment of ISCF's impact against. However, it is important to recognise that later stages of the evaluation will also produce additional data with which to assess the baseline landscape.

Firstly, as noted above, for Challenges where baseline reports have not yet been published, but will be published in the future, key findings from these reports will reviewed be incorporated into this report via an addendum, to be produced once all remaining reports are available. The review of these additional Challenge-level baseline reports will follow the same methodology as used for earlier published reports, with findings coded against the evaluation framework using MaxQDA qualitative data analysis software. Incorporating data from these reports will help to ensure a more holistic coverage of ISCF Challenges in the fund-level baseline.

Secondly, during the econometric analysis conducted in phase 4 of the evaluation, we will collect and analyse data on the economic performance of both ISCF-supported firms and a suitable comparator set of firms *over time*. This data, to be collected through matching of firms to external databases, will provide further data with which to assess the economic landscape prior to the establishment of the ISCF. Data collected through this process will be used, in addition to the present baseline report, when considering the ultimate impact of the Fund. Attempting to collect baseline data from these external databases at this stage would have represented considerable duplication of effort. It is likely that any data collected at this early stage would be incomplete and have gaps (for example, as Challenges may not yet be able to provide full lists of 'treated' firms). This would necessitate collecting and processing this data twice, which is not a trivial task, given the secure access protocols required. It is worth noting that the key value of this data is to trace outcomes over time in the econometric analysis, which though relevant to understanding the baseline landscape, is being used largely to aid the econometric analysis; in addition, it is likely that gaps or incompleteness in the data at this stage (e.g. in Challenges being able to provide full lists of 'treated' firms) would have required us to re-run the analysis again in phase 4 in any case. As a pragmatic, cost-effective approach, we will therefore conduct this exercise once, in phase 4, with the most complete information available.

2.4. Timeframe for the baseline

While the ISCF was announced in 2016, in practice, ISCF Challenges and investments have been established gradually through a series of waves implemented over the subsequent years. The establishment of different ISCF Challenges at different points in time has implications for the timeframe of baselining. This is reflected in the approach to baselining taken by different Challenge-level evaluation teams, with different evaluations adopting different baseline years, depending on the point at which the Challenge was established. Because data collected from Challenge-level baseline reports represents a key source for this baseline report, this has precluded the use of one specific baseline year. As such, this baseline report presents data from across the years in which existing ISCF Challenges have been baselined (in most cases 2017, 2018 or 2019) rather than for one specific year. While adopting this flexible approach to account for the data presented within Challenge-level reports, other baseline methodologies have focused on collecting data for

2018 as the baseline year. Where possible, data retrieved from secondary data sources was collected for 2018.[10] To facilitate focused discussion, the baselining workshops also adopted 2018 as the baseline year.

2.5. Limitations of the baseline approach

Our baselining approach is also subject to a number of important limitations, as described below.

Most significantly, **in many cases it has not been possible to quantitatively baseline evaluation indicators in a meaningful way.** A key factor in this respect has been the variability and inconsistency of baseline data collected by individual Challenge-level evaluations. Each Challenge-level evaluation has its own evaluation framework comprised of indicators specific to the Challenge and its intended outcomes and impacts. As such, the types of baseline data collected are rarely uniform across Challenges. Indeed, even where Challenge-level evaluation indicators are aligned, Challenge-level evaluations have adopted different baselining methodologies or, reflecting the different start dates of Challenges discussed above, conducted baselining with respect to different points in time. Moreover, at the time of writing this report, some Challenge-level evaluations had not completed baseline reports (see Annex A). In view of all the above, the arrival at quantitative baseline figures based on the aggregation of data from Challenge-level baseline reports has in many cases not been possible. The baselining report therefore adopts a more mixed approach. While drawing on quantitative data as presented within Challenge-level baseline reports, this data is combined with quantitative and qualitative insights from other baselining methodologies – for example secondary data and workshop findings – to provide an integrated analysis of the baseline landscape that is descriptive in nature, focusing on key messages that characterise the R&I landscape in the UK prior to the establishment of the ISCF. The implications of this lack of quantitative baseline indicators for later stages of the evaluation are discussed further in Chapter 9 of this report.

While this integrated, descriptive approach has enabled us to draw out key baseline messages, it must also be recognised that **the ISCF is a very diverse fund with Challenges spanning the R&I ecosystem, with the result that the baseline picture is often varied.** In analysing the evidence drawn from across baseline methodologies, we have attempted to draw out cross-cutting insights that capture the Fund-level picture at baseline. However, the diversity of the ISCF Challenges means that what holds for some Challenges may not be true for all. In conducting our analysis, we sought to balance the need for Fund-level messages with capturing the important nuances that exist between individual Challenges.

In some cases, aspects of our Fund-level evaluation framework did not have direct parallels within Challenge-level evaluation frameworks, meaning that no Challenge-level baseline data has been collected. In most cases, this has been overcome by collecting data through other baselining methodologies, for example secondary data sources or baselining workshops. However, **there are some areas of the evaluation framework for which it has not been possible to collect baseline data.** Examples include the collection of baseline data with respect the evaluation question: 'To what extent has the ISCF enhanced understanding of the effectiveness of mission-oriented R&I programmes and informed more effective policymaking for

[10] In cases where this was not possible, e.g. where a source did not contain data for the year 2018, another year (2017 or 2019) was used. For IUK data, to ensure broader coverage across the IUK portfolio, most analysis has considered data on projects commencing in the years 2018, 2019, 2020 and 2021.

mission-oriented goals?' Specific areas of the evaluation framework for which we have not been able to collect baseline data are highlighted in the baseline findings table presented in Annex E. The implications of this for the impact evaluation are also discussed in Chapter 9 of this report.

Finally, though the baseline analysis presented in this report represents an important step in understanding the impact of the ISCF (enabling comparison of the 'before' and 'after' picture of the Fund), and, as noted above, will be supplemented by additional baseline data later in the evaluation, **baselining alone does not provide a sufficient counterfactual with which to assess the impact of the ISCF.** Firstly, any comparison between the achievements of the ISCF and the situation at baseline also requires a consideration of the wider factors that might have contributed to those achievements. Chapter 8 of this report therefore sets out an initial assessment of some key barriers, enablers and dependencies that could support or inhibit the ISCF's progress towards its intended outcomes and impacts. Consideration of these wider barriers and enablers and their interaction with the ISCF will represent an ongoing task throughout the evaluation. Secondly, a meaningful evaluation of the impact of the ISCF will also require the use of counterfactual approaches. This will include the use of a counterfactual set of businesses that did not participate in the ISCF to assess comparative economic performance over time, and a comparator set of non-ISCF IUK awards to which other aspects of the ISCF's performance will be compared. More information on the proposed approach to developing the counterfactual set of businesses is provided in Annex D.

3. Creating knowledge and innovation pathways

A key aim of the ISCF is to create knowledge and advance progress of innovation towards adoption and use. This spans the generation of new knowledge outputs, the advancement and adoption of new technologies and innovations, engagement with different stakeholder groups – including industry, policymakers and the wider public – regarding knowledge and innovation outputs, and the promotion of evidence-based policymaking within the Challenge areas. In this chapter, we set out the baseline picture in each of these areas, through sections focus on:

- **Advancement and adoption of new technologies, products and processes:** Providing baseline evidence for two evaluation questions: 'To what extent has the ISCF advanced the readiness of new technologies, products and processes?' and 'To what extent have ISCF outputs (technologies, products, processes, services, approaches, etc.) been implemented/adopted within society?'
- **Knowledge creation:** Providing baseline evidence for the evaluation question 'What has the ISCF contributed to new knowledge addressing the Challenges, both within the UK and internationally?'
- **Stakeholder awareness:** Providing baseline evidence for the evaluation question 'To what extent has the ISCF leveraged knowledge and insights to create increased awareness and understanding among key stakeholders of new technologies and outputs addressing the Challenges?'
- **Policy landscape:** Providing baseline evidence for the evaluation question 'To what extent has the ISCF contributed to evidence-based policymaking surrounding the Challenges?'

3.1. Advancement and adoption of new technologies, products and processes

Evaluation questions:

1. *To what extent has ISCF advanced the readiness of new technologies, products and processes?*
2. *To what extent have ISCF outputs (technologies, products, processes, services, approaches, etc.) been implemented/adopted within society?*

Overarching key message: New technologies and innovations were already being developed in many Challenge areas at baseline but faced consistent challenges to implementation and adoption at scale.

New technologies and innovations were already being developed in many Challenge areas at baseline. During baselining workshop discussions, stakeholders highlighted a number of areas in which there was considerable activity surrounding the piloting of new technologies and innovations prior to the establishment of the Challenges.[11] Areas highlighted by stakeholders as being already active in this respect included digital health; battery research; carbon capture, utilisation and storage (CCUS); smart local energy systems (SLES); and renewable packaging and agricultural technologies.[12] Data from the UK Innovation Survey provide a broad overview of levels of 'innovation activity'[13] among UK businesses. For the period 2016–2018, these data suggest varying levels of innovation activity by sector[14], with higher levels of activity among businesses within research and experimental development on social sciences and humanities, computing and ICT, and manufacture of transport equipment. Other Challenge-relevant sectors with high levels of innovation activity included architectural and engineering activities and various types of manufacturing, including of fuels, chemicals, food and paper. Figure 5 below presents Innovation Survey data on 'innovation activity' in sectors relevant to ISCF Challenges.

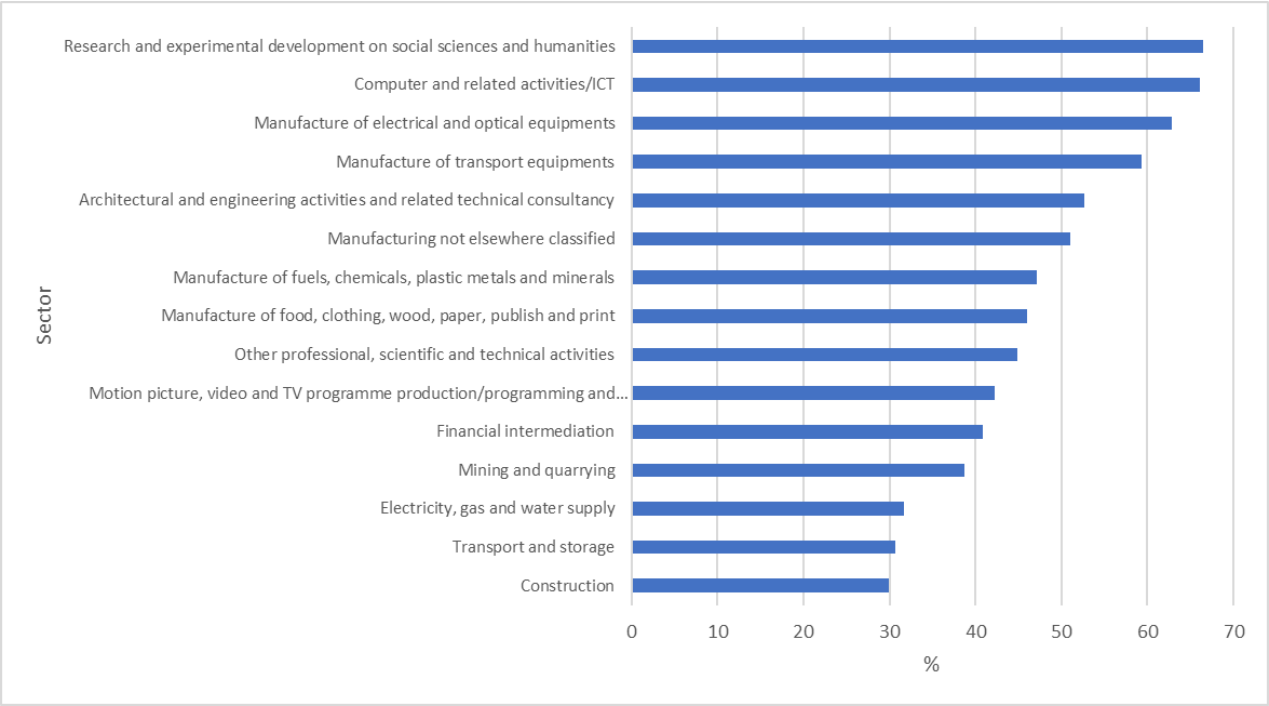
[11] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare,' September 8, 2021; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space,' September 24, 2021; 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy,' September 23, 2021.

[12] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[13] According to the UK Innovation Survey methodology, a business is 'innovation active' when it engages in any of the following activities: a. The introduction of a new or significantly improved product (good or service) or process; b. Engagement in innovation projects not yet complete, scaled back, or abandoned; c. New and significantly improved forms of organisation, business structures or practices, and marketing concepts or strategies.

[14] With respect to sectors, Innovation Survey data refers to Standard Industrial Classification (SIC) codes.

Figure 5: Percentage of 'innovation active' businesses by sector (2016–2018) (ISCF Challenge-relevant sectors only)



Source: RAND Europe analysis of UK Innovation Survey data

3.1.1. Patents and IP

Reflecting the prior existence of innovation activities, the UK had a solid track record of patenting within several Challenge areas at baseline. Evidence available from Challenge-level baseline reports shows that the UK had strong patenting activity in fields related to five Challenges[15]: Data to Early Diagnosis and Precision Medicine, Medicines Manufacturing, Robotics for a Safer World, Quantum Technologies and Faraday Battery. While output in many of these areas was low compared to global leaders – a position occupied in most cases by the United States and China – in many cases, UK patent outputs were either higher or similar to other international comparators such as Germany, France, Canada and Japan. In three areas – Medicines Manufacturing, Faraday Battery and Robotics for a Safer World – UK patents also performed strongly in terms of patent strength.[16] Table 2 presents more information on the baseline performance of UK patents within Challenge-related fields, as presented in Challenge-level baseline reports.

[15] These were the only Challenge-level baseline reports for which baseline patent data was provided.

[16] Patent strength provides a score of the innovative strength of a patent based on factors such as patent age, citations, protected jurisdictions, patent family members and technical breadth. All Challenge-level baseline patent strength analyses were conducted using the same proprietary strength algorithm developed by Clarivate Analytics.

Table 2: Key findings on UK patenting in Challenge-related fields at baseline

Challenge source	Patent outputs	Patent strength
Medicines Manufacturing[17]	• Between 2007 and 2018, UK patent activity in fields related to medicines manufacturing and digital health remained at a steady level, with an average of approximately 570 inventions (DWPI patent families) per year. The total number of UK inventions between 2007 and 2018 was 6,267, accounting for around 2% of global activity. By comparison, the countries with the highest number of inventions across this period were China (239,364 patents, accounting for 66% of global activity) and the USA (74,587 patents, accounting for approximately 21% of global activity). Within the European region, the UK had the second highest number of patent filings behind Germany (9,042 patents, approximately 2.5% of global activity).	• The average patent strength score of UK patents was 44.8, higher than China (17.8), the USA (40.5) and South Korea (32.5). 47% of UK patents in medicines manufacturing and digital health fields were classified as 'very strong'. For comparator countries, the average share of patents given this classification was only 15%.
Faraday Battery[18]	• Between 2007 and 2018, the UK ranked fifth in this field in patent activity associated with battery technologies. However, of a total of 110,000 inventions (DWPI patent families) filed during this period, the UK accounted for only 2,251, (approximately 2%). The countries with the highest inventive activity in the period were Japan (64,837 inventions) and the USA (27,870 inventions). Germany accounted for 11,892 inventions, while France performed at a similar level to the UK, with 2,683 inventions. Notably, UK patent performance decreased steadily from 2012 onwards (following increases between 2007 and 2012).	• The average strength of UK patents between 2007 and 2018 was 34, placing the UK fifth globally behind Sweden, the USA, France and Spain. 22% of UK patents are classed as 'very strong' with 24% classed as 'somewhat strong'.
Robotics for a Safer World[19]	• Of a total of 3,727 inventions (DWPI patent families) mentioning concepts of robotics and AI in extreme environments between 2010 and 2017, the UK accounted for a total of 231, or 6%. The USA and Japan were the most active countries in this space, accounting for approximately 58% and 15% of global activity respectively. The UK was ahead of competitors such as Germany, France, India, Canada and Israel.	• The average strength of UK patents between 2010 and 2017 was 41.7, higher than Japan (28.5), Germany (37.3) and India (32.1) but lower than Israel (53.9), the USA (42.7) and France (44.3). 51% of UK patents were classified as 'strong', compared to 47% patents from non-UK countries.

[17] Ipsos MORI, Technopolis Group, and George Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report,' April 2019.

[18] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report,' August 2019.

[19] Technopolis Group and Ipsos MORI, 'ISCF Robotics and Artificial Intelligence in Extreme Environments - Baseline and Process Evaluation Report,' April 2019.

Quantum Technologies[20]	• The UK ranked fifth in the world in quantum technology patenting at baseline, with 147 quantum technology patents obtained between 1990 and 2017. The position of the UK within the top five countries has been consistent throughout this period. The USA and China are the leading players in the quantum technology space, having obtained 1,345 and 643 patents respectively between 1990 and 2017. However, UK output compares favourably to Germany and Canada, two comparator countries used for the baseline analysis.	-
Data to Early Diagnosis and Precision Medicine[21]	• At baseline, in 2017, the number of UK 'medtech' patent applications was 374.	-

Source: RAND Europe analysis of Challenge-level baseline reports

In terms of the patent activity of ISCF participant organisations, findings from Challenge-level baseline reports suggest that there was some activity in this area at baseline. Indeed, where data on the baseline patent activity of Challenge applicants or participants was captured, on average, somewhere between a quarter and a third of respondents had applied for IP relating to their ISCF projects at baseline.[22] A baseline survey of applicants (successful and unsuccessful) to the Medicines Manufacturing Challenge, for example, showed that 27 per cent had registered IP (in the form of patents, designs, trademarks or copyrights) related to their proposed project at the time of application, of which 14 per cent had already licensed their IP.[23] Meanwhile, a baseline survey of successful applicants to the Robotics for a Safer World Challenge found that around one third had prior IP activity related to Robotics for a Safer World.[24]

Figure 6 and Figure 8 present data on the IP activities of IUK projects at baseline. Figure 6 presents the number of IUK projects reporting that they had been granted or applied for IP rights for patents developed *jointly*, while Figure 7 presents the number of projects reporting that they had been granted or applied for IP rights *solely*. In both cases, the data covers the IUK portfolio excluding projects funded under the ISCF and is based on reporting in PCFs, with data presented by project start date.[25] This analysis of baseline IP

[20] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report,' June 2021.

[21] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report,' July 2021.

[22] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report'; Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

[23] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report.'

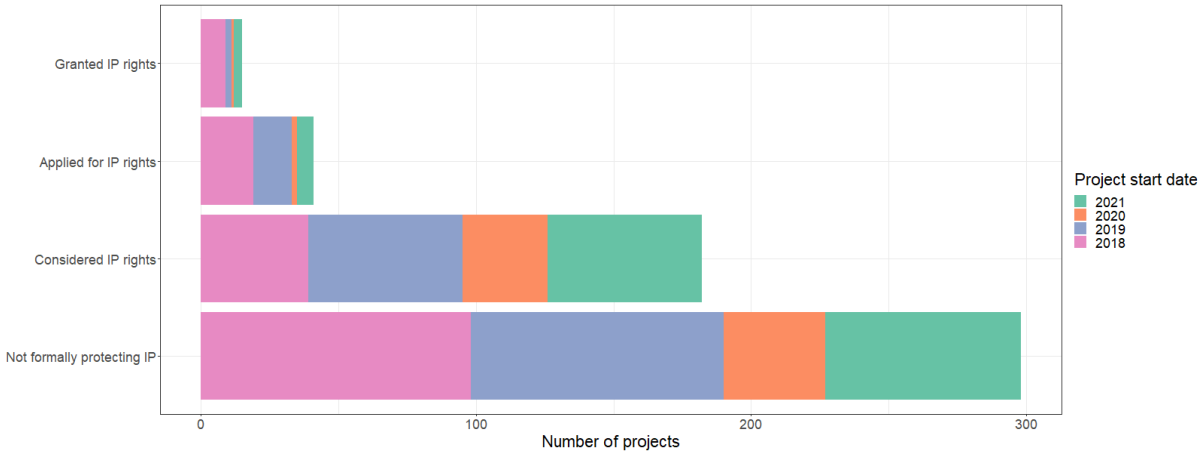
[24] Technopolis Group and Ipsos MORI, 'ISCF Robotics and Artificial Intelligence in Extreme Environments - Baseline and Process Evaluation Report.'

[25] While the data presented here provide a general sense of IP activities of IUK projects, it should be noted that data collected through PCFs may be subject to under-reporting.

activity of non-ISCF IUK projects provides an overall benchmark against which to compare the IP activity of ISCF-funded projects during the later impact evaluation.

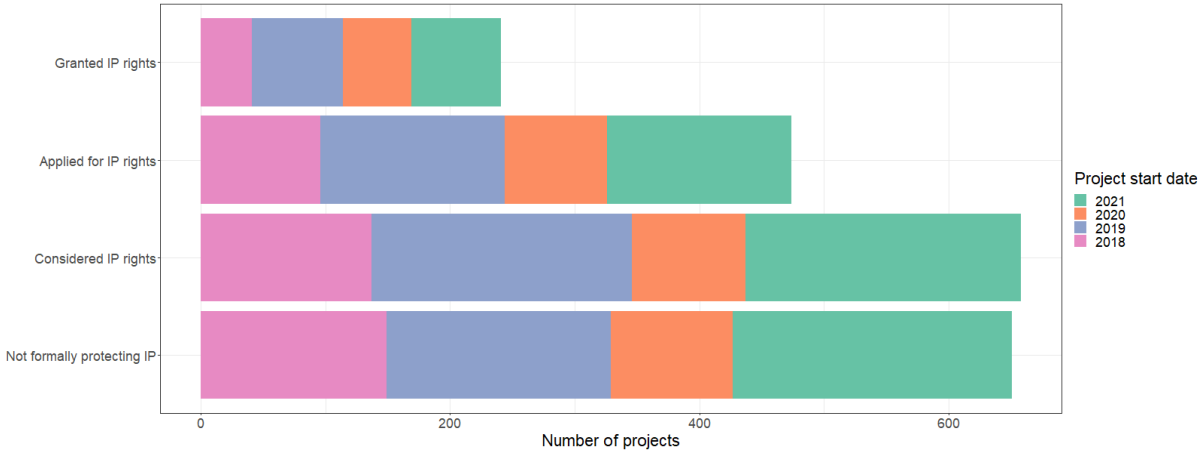
Figure 6 and Figure 7 show that in both cases, a majority of IUK projects had either no formally protected IP or had considered but not applied IP rights. By comparison, a smaller proportion of projects reported having been granted, or applying, for IP rights, particularly the case of jointly developed patents. The picture was similar for projects commencing in 2018, 2019, 2020 and 2021.

Figure 6: Number of IUK projects reporting IP activities relating to jointly developed patents



Source: RAND Europe analysis of IUK data

Figure 7: Number of IUK projects reporting IP activities relating to solely developed patents (2018–2021)



Source: RAND Europe analysis of IUK data

3.1.2. New products and services

In some Challenge areas, there is evidence that new or improved products and services were being developed at baseline. For example, a baseline survey of participants in the Audience of the Future Challenge showed that, on average (mean), 2.40 new creative immersive products and 2.55 new creative

immersive services had been developed by participant organisations during the previous two years.[26] A baseline survey of businesses participating in the Creative Industries Clusters Programme found that 60 per cent of businesses had developed at least one product, tool or service over the period 2017–2020, with 35 per cent of businesses reporting the development of more than one product, tool or service. Moreover, 26 per cent of Cluster businesses reported that they had brought one product, tool or service to market during this time, with 12 per cent of businesses having brought at least two.[27] A survey conducted to baseline the Data to Early Diagnosis and Precision Medicine Challenge found that 70 per cent of precision medicine firms surveyed had introduced new or significantly improved products, processes or services during the previous three years.[28] Meanwhile, 55 per cent of foundation industry company respondents to a Transforming Foundation Industries baseline survey reported introducing new or significantly improved products in the previous financial year (2019/20), with 49 per cent reporting that they had introduced new or significantly improved processes during that time.[29] Challenge-level baselining suggests that business participants had more experience in the development of new or improved products and services than academic counterparts.[30] At the same time, Challenge-level baselining also highlighted some areas where the development of new or improved products and services was more limited. A baseline survey of applicants to the Quantum Technologies Challenge, for example, found that only 4 per cent of business applicants had launched a new quantum technology-related or -enabled product or service to market during the previous five years.[31]

3.1.3. New business models

There is also evidence that new business models were being established in some Challenge areas at baseline. Among successful applicants to the Audience of the Future Challenge, for example, a baseline survey showed that the average (mean) number of new business models trialled or tested during the previous two years was 1.34, with the majority of activity surrounding innovative business models taking place in the immersive sector.[32] Meanwhile, a baseline survey of applicants to the Next Generation Services Challenge found that 47.3 per cent of successful end-user applicants had trialled or tested new business models within the past two years.[33] One example of a new business model trialled includes the use of AI

[26] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report,' April 2020.

[27] Frontier Economics and BOP Consulting, 'Evaluation of the Creative Industries Clusters Programme - Phase 2 Baseline and Initial Impact Reporting - the CRPDs' 2021.

[28] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report'

[29] SQW, 'Transforming Foundation Industries: Industrial Strategy Challenge Fund Evaluation - Baseline Report' May 2021.

[30] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report'

[31] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report'

[32] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report'

[33] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft'

and machine learning technologies to enable at-scale practices of previously unscalable business practices (e.g. accountancy services).[34]

3.1.4. Technology readiness

In most cases, ISCF-funded projects were at a relatively early stage of readiness at baseline, with most projects reporting Technology Readiness Levels (TRL) of 1 to 4. This is illustrated by Figure 8 below, which presents findings on the TRL of ISCF-funded projects as derived from Challenge-level baselining reports. Challenges whose projects focused around TRLs 1 to 4 include Audience of the Future, Future Flight, Quantum Technologies, Medicines Manufacturing, Faraday Battery, Low Cost Nuclear and Prospering from the Energy Revolution, suggesting that an early stage of readiness was common across different sectors. A small number of projects within the Audience of the Future and Quantum Technologies Challenges were already at an advanced state of readiness, i.e. TRLs 8 or 9.[35]

Notably, within individual Challenges, TRLs often varied across different funding streams. Within the Audience of the Future Challenge, for example, projects funded by the Challenge's Investment Accelerator strand typically had a higher TRL than those under the Production Innovation and Immersive Content and Design Foundations strands.[36] Similarly, Prospering from the Energy Revolution Key Technology Component projects had a higher TRL on average than projects funded under the Fast Start strand.[37]

[34] Technopolis Group.

[35] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report'

[36] Technopolis Group and BOP Consulting.

[37] Ipsos MORI and Technopolis Group, 'Industrial Strategy Challenge Fund: Prospering from the Energy Revolution - Evaluation Baseline Report' October 2020.

Figure 8: Key findings on TRLs of Challenge projects at baseline

<table>
<tr><th></th><th>Audience of the Future</th><th>Future Flight</th><th>Prospering from the Energy Revolution</th><th>Quantum Technologies</th><th>Medicines Manufacturing</th><th>Faraday Battery</th><th>Low Cost Nuclear</th></tr>
<tr><td>TRL 1</td><td rowspan="2">59% of successful applicants to were at TRL 1–2</td><td rowspan="2">33% of successful applicants projects at TRL 1–2</td><td rowspan="3">Most Fast Start projects at TRL 1–3
Key Technology Component projects at an average TRL of 3.66</td><td></td><td></td><td></td><td></td></tr>
<tr><td>TRL 2</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>TRL 3</td><td rowspan="2">28% of successful applicants were at TRL 3–4</td><td rowspan="2">37% of successful applicants projects at TRL 3–4</td><td rowspan="2">49% of projects at TRL 3–4</td><td rowspan="2">58% of CR&D projects and 54% of DHTC at TRL 3–4</td><td>Most CR&D projects at TRL 3</td><td rowspan="3">Key UKSMR programme innovations at TRL 3–5</td></tr>
<tr><td>TRL 4</td><td></td><td></td><td></td></tr>
<tr><td>TRL 5</td><td rowspan="2">6% of successful applicants were at TRL 5 or 6</td><td rowspan="3">32% of successful applicants had projects at TRL 5–7</td><td></td><td rowspan="2">40% of projects reported at TRL 5–TRL 6</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>TRL 6</td><td>Four Key Technology Component projects at TRL of 6</td></tr>
<tr><td>TRL 7</td><td rowspan="2">4% of successful applicants were at TRL 7 or 8</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>TRL 8</td><td>Four organisations reported key products at TRL 8–9</td></tr>
<tr><td>TRL 9</td><td>At baseline, 4% of successful applicants were at TRL 9</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Source: RAND Europe analysis of Challenge-level baseline reports

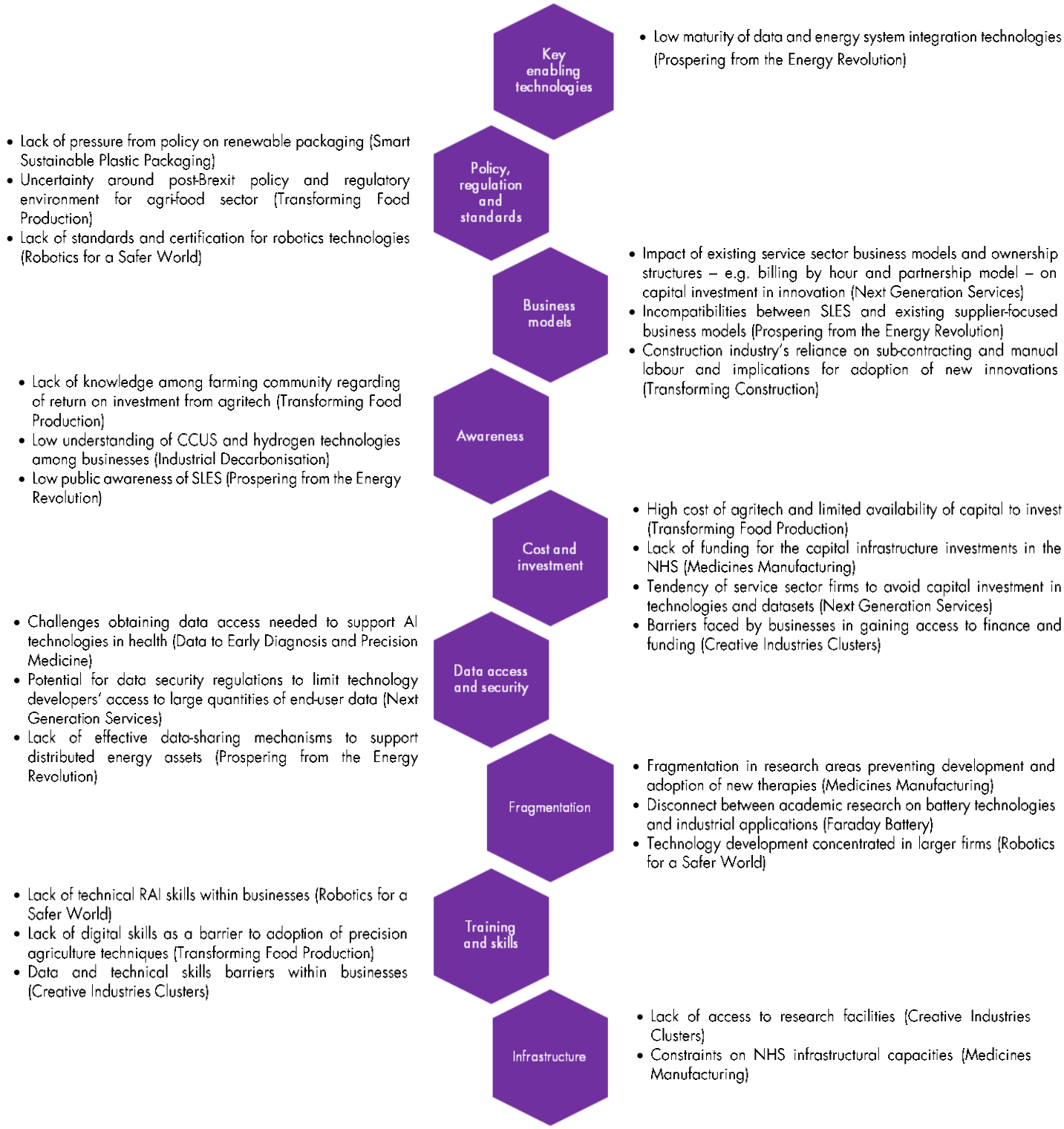
3.1.5. Barriers to the advancement and adoption of technologies and innovations

While there is evidence of innovation activities across the Challenge areas at baseline (as presented above), across all Challenge areas, there were also consistent obstacles preventing the adoption of new technologies and innovations at scale. Indeed, evidence derived from Challenge-level baselining reports and Fund-level baselining workshops identified wide-ranging barriers to the scale-up of new technologies and innovations, including many common barriers across different Challenge areas. Key themes highlighted included barriers relating to: the maturity of key enabling technologies; policy, regulatory and standards frameworks; existing business models; stakeholder awareness; costs and investment; data access and security; fragmentation; training and skills; and infrastructure.

Figure 9 below provides specific examples of issues pertaining to each of these themes drawn from across the Challenge areas, drawing on evidence from Challenge-level baselining and Fund-level baselining workshops. The list of examples is not intended to be exhaustive. Rather, the intention is to provide an illustrative overview of different types of barriers to scale-up and adoption encountered across different Challenge areas at baseline.

Notably, several of the themes highlighted as key barriers to adoption are aligned with the objectives of the ISCF as set out in the Fund-level Theory of Change. For example, where evidence suggests that a lack stakeholder awareness is a common barrier to adoption of technologies and innovations within the Challenge areas, the generation of increased stakeholder awareness of technologies and innovations addressing the Challenges is also an explicit element of the ISCF ToC. As such, a more detailed analysis of the baseline situation with respect to several of the barriers set out in Figure 9 is presented throughout this report. In addition to further analysis of stakeholder awareness and policy landscapes at baseline (the remaining sections of this chapter), this includes further consideration of the baseline context surrounding investment and skills (Chapter 4) and networks and collaboration (Chapter 5).

Figure 9: Common barriers to scale-up of new technologies and innovations across Challenge areas



Source: RAND Europe analysis of Challenge-level baseline reports/Fund-level baselining workshops

3.2. Knowledge creation

Evaluation question: What has the ISCF contributed to new knowledge addressing the Challenges, both within the UK and internationally?

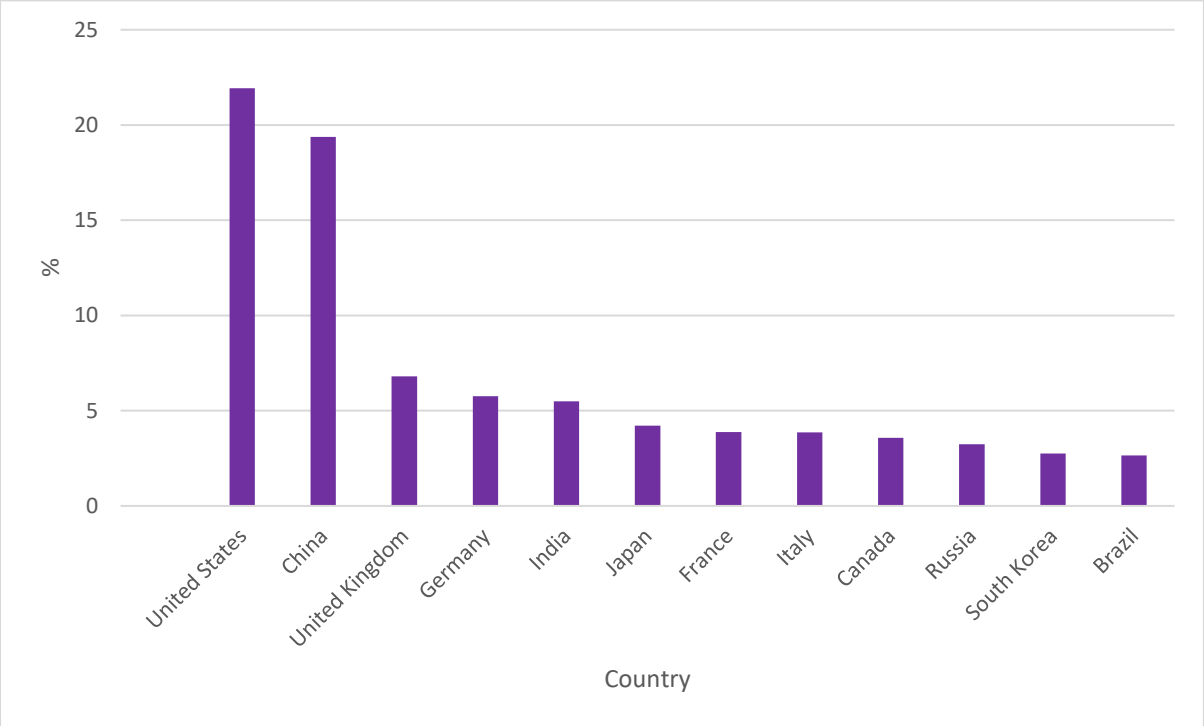
Key message: The UK has a strong track record in terms of publications output and quality, which was reflected in several Challenge areas at baseline. At the same time, there were some Challenge areas in which publications output was low, or where publications were not a focus.

At baseline, the UK had a strong publications[38] track record relative to the country's size and scale of R&D investment. According to Scopus data, the UK published 212,876 publications in 2018, equating to 7 per cent of the total world publications output and the third highest share of publications behind the United States and China (Figure 10). UK publications were also highly cited, with the UK recording the highest field-weighted citation impact (FWCI)[39] among G7 and other comparator countries, a position it has held since 2007 (Figure 11).

[38] The analysis here focuses on UK performance with respect to peer-reviewed academic publications. While academic publications are used here as a proxy for knowledge creation, there are certain limitations that are important to recognise. For example, the generation of 'new' knowledge may not be a requirement for all publications, and some publications, e.g. replication studies, reviews, may have other purposes than the creation of new knowledge *per se*. Equally, it is not the case that all new knowledge is published in academic publications. Some new knowledge may be published in other forms (e.g. grey literature and reports), while other knowledge may not be published at all.

[39] FWCI compares the actual number of citations received with the average number of citations received by publications published in the same year, discipline, and format (book, article, review, conference paper). A value of 1.0 represents the world average. The overall FWCI presented in Figure 11 is the average of the FWCI for each specific publication.

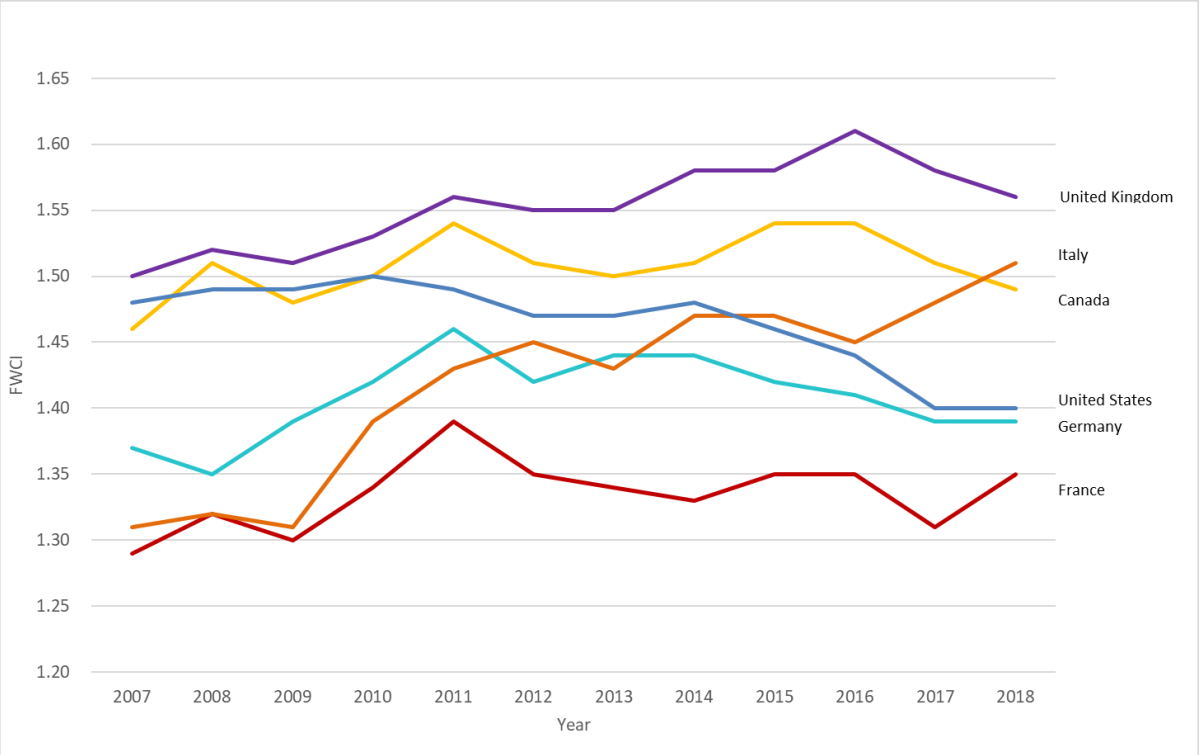
Figure 10: Share of the world's publications by country (2018)[40]



Source: RAND Europe analysis of Scopus data compiled by BEIS

[40] Data compares UK with all G7 countries (Canada, France, Germany, Italy, Japan and the United States), as well as Brazil, China, India, Russia, and South Korea.

Figure 11: Field-weighted citation impact by country (2007–2018) [41]



Source: RAND Europe analysis of Scopus data compiled by BEIS

The UK's strong track record in terms of publications output and quality was reflected in several Challenge areas at baseline. Looking at the publication output of individuals funded through ISCF Challenges over the period 2014–18 (i.e. prior to award), for those Challenges where we were able to match individuals in the bibliometric database, the performance was strong, with the normalised citation numbers and the proportion of publications which were highly cited well above world average (Figure 12), as well as above UK average performance as indicated in Figure 11. The average Field Citation Ratio at baseline across the Fund was 4.32, and 18 per cent of the prior articles were in the top 5 per cent of most highly cited articles. However, for some Challenges the numbers of articles identified is small, and as such the analysis should be treated with caution, as shown in Figure 12. Further, for four Challenges[42] we were unable to match any funded individuals with publications in the bibliometric database, and for another Challenge[43] individuals matched were not associated with any articles published in the timeframe (2014–2018) and as such are not included in this analysis.

[41] Data compares UK with all G7 countries (Canada, France, Germany, Italy, Japan and the United States), as well as Brazil, China, India, Russia and South Korea. Some countries have been removed from the graph for presentational purposes.

[42] Accelerating Detection of Disease, Low Cost Nuclear, National Satellite Test Facility, Self Driving Vehicles

[43] Next Generation Aerospace

Figure 12: Analysis of baseline publication output of individuals associated with the ISCF (2014–2018)[44]

Challenge	Number of publications	Number of Articles	Average Field Citation Ratio (FCR)	Number of highly cited articles	% highly cited articles
Prospering From the Energy Revolution	828	601	6.19	154	26%
Manufacturing Made Smarter	29	25	6.08	5	20%
Quantum Technologies Wave 2	140	61	5.97	15	25%
Transforming Foundation Industries	219	206	5.39	53	26%
Next Generation Services	323	182	5.30	31	17%
Robotics for a Safer World	3655	1878	5.11	272	14%
Transforming Construction	1861	1334	4.34	236	18%
Future Flight	3	3	4.23	0	0%
Data To Early Diagnosis and Precision Medicine	4714	4242	4.22	802	19%
Audience of the Future	120	87	4.21	15	17%
Smart Sustainable Plastic Packaging	1035	925	3.98	134	14%
Industrial Decarbonisation	1690	1500	3.84	265	18%
Digital Security by Design	1013	303	3.69	29	10%
Healthy Ageing	1873	1513	3.59	183	12%
Transforming Food Production	69	48	3.50	8	17%
Commercialising Quantum Wave 3	103	45	3.03	6	13%
Medicines Manufacturing	185	144	2.81	16	11%
Faraday Battery Challenge	73	53	1.95	5	9%
Driving the Electric Revolution	2	2	0.00	0	0%

Source: RAND Europe analysis of Dimensions data provided by Digital Science.

[44] Average Field Citation Ratio gives the average number of citations per publication normalised for field and year of publication. Number and percentage of highly cited articles refers to those in the top 5% for the number of citations for the year and field of publication.

The UK's strong publications track record is supported by the evidence from the available Challenge-level baseline reports, which suggest that the UK performed strongly in fields relating to the Robotics for a Safer World, Industrial Decarbonisation, Faraday Battery and Quantum Technologies.[45] Between 2009 and 2017, for example, the UK had the third highest publications output of all countries in fields relating to the Robotics for a Safer World, with papers in these fields also performing strongly compared to international comparators in terms of average citation impact and inclusion within the top 10 per cent most highly cited papers.[46] Table 3 below presents information on the baseline performance of UK publications within Challenge-related fields as presented in Challenge-level baseline reports.

[45] Baselining of the Data to Early Diagnostics and Precision Medicine Challenge showed that publications in relevant fields had been growing in the years 2011–2017. However, no information was provided on how these numbers compared to international comparators.

[46] Technopolis Group and Ipsos MORI, 'ISCF Robotics and Artificial Intelligence in Extreme Environments - Baseline and Process Evaluation Report'.

Table 3: Key findings on UK publications in Challenge-related fields at baseline

Challenge	Publications outputs	Citation metrics
Robotics for a Safer World[47]	• Between 2009 and 2017, the annual number of UK papers on robotics and AI in extreme environments rose from 30 to 79. Overall, 466 UK papers were published during the period, the third highest output behind the USA (1,671 publications) and China (989 publications).	• In terms of the number of highly cited papers produced (those in the top 10% in terms of citation counts), the UK also ranked third globally (71). • Between 2009 and 2017, UK publications shared a similar category normalised citation impact as six other countries (China, the USA, France, Germany, Italy and Spain), with an average category normalised citation impact of 1.2 in 2017. This puts UK publications above the world average (set at the value of one) in terms of their citation impact.
Industrial Decarbonisation[48]	• Between 2010 and 2018, UK publication outputs in fields related to industrial decarbonisation accounted for 28% of overall global research in these fields. However, UK academic production in these fields has been growing less quickly than non-UK research.	• Between 2010 and 2018, the average citation impact factor of UK publications was significantly higher than that of non-UK academic publications. However, the average impact factor of both UK and non-UK publications in industrial decarbonisation fields has been decreasing over time.
Faraday Battery [49]	• Between 2008 and 2017, the annual number of UK papers on battery technologies rose from 41 to 322. Overall, however, the UK ranked 10th worldwide in publications output (with a total of 1,731 papers) and significantly behind the two largest publishing countries of China (29,950 publications) and the USA (12,550 publications).	• The average category normalised citation impact (CNCI) of the UK's battery research papers remained at or above 1.5 times the world average between 2008 and 2017. The average citation impact of UK battery research papers over the period was higher than eight other comparator countries used in baselining analysis (China, Germany, Spain, France, South Korea, Japan, Taiwan and India). However, the UK's CNCI ranking was at its highest in 2010–2012 and has since fallen with other countries producing higher average CNCI scores.
Quantum Technologies[50]	• In 2017, UK papers accounted for 9% of the world's total quantum technology publications (though this number reduces to 5% when 'fractional counting', which allocates authorship proportionally to each author of a paper, is applied). In terms of total number of papers, the UK ranks 4th behind China, the USA and Germany. Between 2008 and 2017, the number of UK quantum technology papers saw a compound annual growth rate of 5.76%).	• The UK also performs above world averages across all citation impact indicators for quantum technology papers, including metrics for the number of papers within the top 10% (HCP10 = 1.52) and 1% (HCP 1 = 1.6) most highly cited papers (HCPs). In citation performance, UK papers performs better than Germany and Canada but are outperformed by the USA, Austria, Switzerland and the Netherlands.

[47] Technopolis Group and Ipsos MORI.

[48] Ipsos MORI, 'Industrial Decarbonisation Challenge - Baseline Report' March 2021.

[49] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report'.

[50] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report'.

Data to Early Diagnosis and Precision Medicine[51]	• According to an analysis of PubMed, in 2017, the number of UK publications relating to Genomics and Genetics was 1,273. 442 UK publications related to precision or personalised medicine, 232 to precision diagnosis or early diagnosis and 193 to pharmacogenomics or pharmacogenetics. 52 UK publications were published relating to AI and machine learning, with 20 UK publications relating to digital health. The number of UK publications relating to genomics, AI/machine learning or precision/personalised medicine increased consistently between 2011 and 2017.	-

Source: RAND Europe analysis of Challenge-level baseline reports

As Table 3 illustrates, **while UK publications performance was strong in these Challenge areas, there was also room for growth.** In fields relating to the Faraday Battery Challenge, for instance, despite a growing number of UK papers between 2008 and 2017, the UK ranked 10th worldwide in publications output, behind China, the United States, South Korea, Japan, Germany, India, Australia, France and Canada.[52] Moreover, the UK's average category normalised citation impact (CNCI)[53] ranking has fallen since 2010–2012, with other countries producing higher average CNCI scores.[54] In fields relating to the Quantum Technologies Challenge, the citation performance of UK publications was higher than several comparators, but lower than the United States, Austria, Switzerland, and the Netherlands.[55]

Figure 13 below presents data on the publications output of IUK projects at baseline. Specifically, the figure presents the number of IUK projects reporting that they have produced publications, with data presented by project start date. The data cover the IUK portfolio excluding projects funded under the ISCF and is based on reporting in PCFs.[56] The analysis excludes projects reporting no publications, or with publications that were not an applicable output. This shows that among projects reporting publication outputs across all start dates, the highest proportion of projects reported that they produced one publication.

[51] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report.'

[52] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

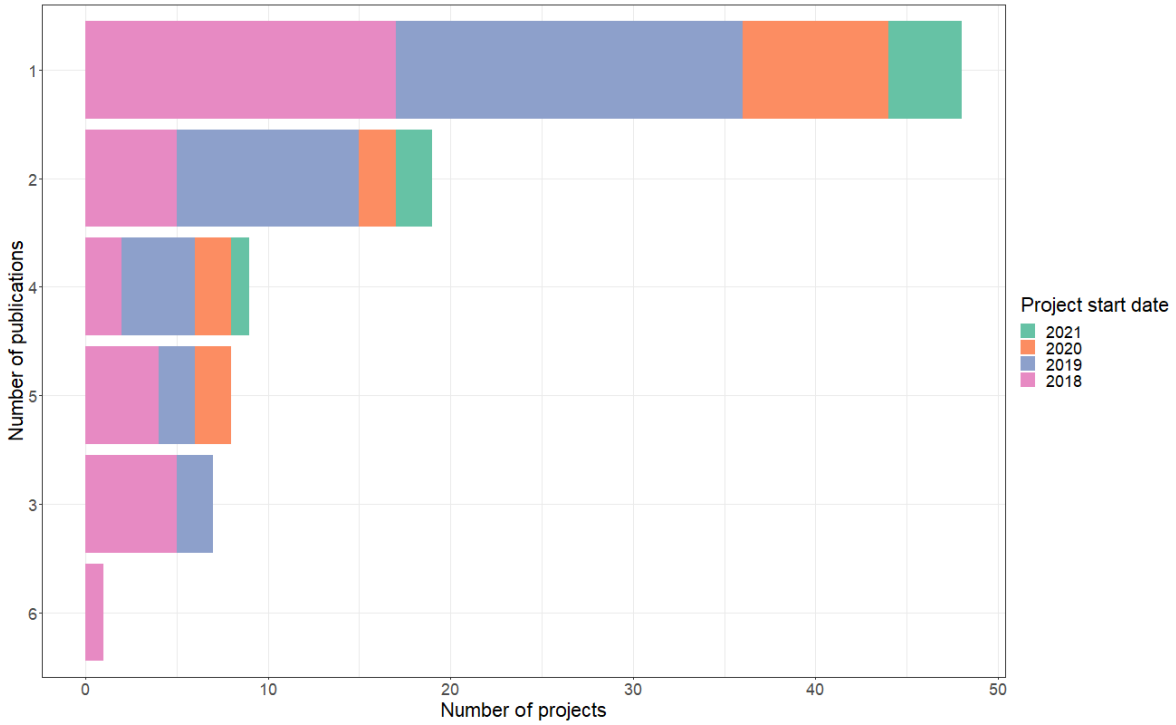
[53] CNCI is calculated by dividing the actual citation count of a publication by the expected citation rate for publications with the same document type, year of publication and subject area.

[54] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

[55] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report.'

[56] While the data presented here provide a general sense of publications outputs of IUK projects, it should be noted that data collected through PCFs may be subject to under-reporting.

Figure 13: Number of IUK projects reporting the publications produced (2018–2021)



Source: RAND Europe analysis of IUK data

In some cases, there was a recognised need for other forms of knowledge creation at baseline. Specifically, as highlighted by baselining of the Data to Early Diagnostics and Precision Medicine Challenge, stakeholders within the precision medicine field felt that the creation of larger, more complex and representative datasets – building on the opportunity of the UK Biobank – was necessary, as was the need to connect these datasets to existing patient data in order to generate meaningful clinical insights.[57]

3.3. Stakeholder awareness

Key message: There were gaps in awareness and engagement of policy, industry and wider public stakeholders at baseline, though the extent of these gaps varied across Challenge areas, and there is some evidence of efforts to engage a wider audience with R&I.

Evaluation question: To what extent has the ISCF leveraged knowledge and insights to create increased awareness and understanding among key stakeholders of new technologies and outputs addressing the Challenges?

There was general awareness of R&I opportunities within the Challenge areas among policymakers at baseline. However, in many cases, awareness of the specific needs of the Challenges was low, with gaps in policymakers' understanding and engagement. For example, while there was good awareness of the economic contribution of the creative sector to the UK, the role of R&I within the creative industries was

[57] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report.'

not well understood by policymakers.[58] In the energy space, notwithstanding growing recognition of developments in SLES (both in UK regions and internationally), the predisposition of UK policymakers was towards a centralised national energy system rather than the development of local energy networks.[59] In the case of nuclear energy, there was good engagement from local authorities at baseline (for example, competition between local authorities to be the host site for the first small modular reactor (SMR)) but more limited support from policy teams within national government bodies, such as the Department for Business Energy and Industrial Strategy (BEIS).[60] Reflecting this, the regulatory approvals processes for SMR were burdensome at baseline.[61] Notwithstanding some important interventions addressing digital technologies and construction, such as the Building Information Modelling (BIM) Level 2 mandate, the digital construction space also marked significant gaps in the engagement of policymakers and regulators at baseline.[62]

Evidence was already being used to inform policy in some of these areas at baseline, as shown in Figure 14. Looking at publications by ISCF award holders prior to award (2014–2018), across the Fund 4.7 per cent of these were cited in policy documents. The level varies between Challenges, with some areas – notably Prospering from the Energy Revolution, Data to Early Diagnosis and Precision Medicine, and Industrial Decarbonisation – having higher proportions of their publications cited in policy documents. We note that in some areas we were unable to identify prior baseline publications by ISCF award holders. In addition, this is a partial, indicative picture of influence on policy.

[58] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data,' September 13, 2021.

[59] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[60] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[61] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[62] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability,' October 7, 2021.

Figure 14: Baseline levels of citation in policy documents, including publications (2014–2018) for ISCF award holders matched in Dimensions

Challenge area	Number of publications	Policy citations	Percentage of publications cited in policy documents
All ISCF	16946	789	4.7%
Accelerating Detection of Disease	0	0	N/A
Audience of the Future	120	3	2.5%
Commercialising Quantum Wave 3	103	1	1.0%
Data To Early Diagnosis and Precision Medicine	4714	370	7.8%
Digital Security by Design	1013	12	1.2%
Driving the Electric Revolution	2	0	0.0%
Faraday Battery Challenge	73	0	0.0%
Future Flight	3	0	0.0%
Healthy Ageing	1873	85	4.5%
Industrial Decarbonisation	1690	115	6.8%
Low Cost Nuclear (Phase 1)	0	0	N/A
Manufacturing Made Smarter	29	0	0.0%
Medicines Manufacturing	185	9	4.9%
National Satellite Test Facility	0	0	N/A
Next Gen Aerospace	1	0	0.0%
Next Generation Services	323	15	4.6%
Prospering From the Energy Revolution	828	92	11.1%
Quantum Technologies Wave 2	140	1	0.7%
Robotics for a Safer World	3655	24	0.7%
Self Driving Vehicles	0	0	N/A
Smart Sustainable Plastic Packaging	1035	31	3.0%
Transforming Construction	1861	79	4.2%
Transforming Food Production	69	4	5.8%
Transforming Foundation Industries	219	9	4.1%

Source: RAND Europe analysis of Dimensions data provided by Digital Science.

Awareness of businesses regarding R&I opportunities within the Challenge areas was varied at baseline, with gaps in some areas. In the SMR space, awareness of businesses was considered to be good, as demonstrated by the large number of company responses to a UK government Request for Information (RFI) on small reactor financing in 2015.[63] Similarly, within the services and farming sector, baseline surveys demonstrated good levels of interest among businesses in opportunities to gain access to information about Challenge-relevant technologies and innovations.[64] By comparison, awareness of business in other

[63] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[64] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft'; SQW, 'Transforming Food Production Evaluation - Baseline: Overview Report,' July 2021. Next Generation Services: Specifically, 66% of non-NGS applicant members of the NGS Challenge's AI for Services network were attracted by opportunities to get access to information about the latest trends in AI and data applications in the service sectors Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'. Transforming Food Production: Awareness of the innovative agriculture technologies/practices covered in the survey was high, notably for 'Data recording/collection systems or technologies', 'Automation/control systems or technologies', and 'Biochemicals' SQW, 'Transforming Food Production Evaluation - Baseline: Overview Report.'

Challenge areas was low. A baseline survey found low understanding of CCUS and hydrogen technologies outside the IDC programme at baseline, with two thirds of respondents (67 per cent) having never heard of their nearest decarbonisation Cluster Plan.[65] Moreover, within the CCUS sector, awareness of business varied by business size, with small and medium-sized enterprises (SMEs) reported to be more aware of public funding opportunities than larger firms.[66] In the battery sector, there was a long-standing disconnect between academic research and industrial innovation at baseline. However, there was also awareness within both academic and industrial camps of opportunities for collaboration in this space.[67] A baseline survey of Transforming Construction Challenge beneficiaries – one third of which were industry respondents – showed that awareness of different tools and technologies supported by the Challenge varied depending on the type of tool and technology.[68]

While there was limited evidence regarding the extent of wider public awareness at baseline, evidence from baselining workshops suggests a general lack of public awareness across Challenge areas. A survey conducted by the Energy Revolution Integration Service (ERIS) showed broad positivity in public attitudes towards SLES concepts such as peer-to-peer trading, demand-side response, heat as a service and vehicle to grid[69],[70]. By contrast, however, within the SMR space, only 18 per cent of respondents to a BEIS public attitudes tracker reported any awareness of SMRs.[71] In baselining workshops, stakeholders from across Challenge areas reported a general lack of public awareness and engagement at baseline.[72]

There is evidence, however of efforts to communicate R&I to a wider audience at baseline. Evidence from scientometric analysis suggests that there was wider communication of outcomes of research prior to the programme based on Altmetric data (Figure 15). Over half of award holders' prior publications (in the period 2014–2018) had some Altmetrics associated with them. The average Altmetric score for the baseline set as a whole is 31.20. There is also significant variation by Challenge area, though we note that for some Challenges a low number of publications were matched, so in those cases the data should be interpreted with caution.

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[65] Ipsos MORI, 'Industrial Decarbonisation Challenge - Baseline Report.'

[66] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[67] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[68] Frontier Economics, 'Transforming Construction Challenge - Baseline Report,' May 2020.

[69] Ipsos MORI and Technopolis Group, 'Industrial Strategy Challenge Fund: Prospering from the Energy Revolution - Evaluation Baseline Report,'

[70] However, it was also suggested that end-user testing was considered necessary to understand more about consumers' first-hand experience of these concepts.

[71] RSM, 'Low Cost Nuclear Challenge Evaluation: Work Package 2: Baseline Report,' May 2021.

[72] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space'; 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

Figure 15: Altmetrics data on baseline publication set comprising publications by ISCF award holders (2014–2018)

Challenge area	Number of publications	Number of publications with Altmetrics	Percentage of publications with Altmetrics	Average Altmetric score
All ISCF	16946	8656	51.1%	31.20
Accelerating Detection of Disease	0	0	0.0%	0.00
Audience of the Future	120	74	61.7%	25.34
Commercialising Quantum Wave 3	103	31	30.1%	20.35
Data To Early Diagnosis and Precision Medicine	4714	3210	68.1%	46.62
Digital Security by Design	1013	321	31.7%	19.44
Driving the Electric Revolution	2	0	0.0%	0.00
Faraday Battery Challenge	73	47	64.4%	5.70
Future Flight	3	2	66.7%	1.00
Healthy Ageing	1873	1002	53.5%	47.58
Industrial Decarbonisation	1690	648	38.3%	20.01
Low Cost Nuclear (Phase 1)	0	0	0.0%	0.00
Manufacturing Made Smarter	29	6	20.7%	4.50
Medicines Manufacturing	185	86	46.5%	24.27
National Satellite Test Facility	0	0	0.0%	0.00
Next Generation Aerospace	1	1	100.0%	3.00
Next Generation Services	323	128	39.6%	16.29
Prospering From the Energy Revolution	828	352	42.5%	47.90
Quantum Technologies Wave 2	140	98	70.0%	8.19
Robotics for a Safer World	3655	1561	42.7%	10.63
Self Driving Vehicles	0	0	0.0%	0.00
Smart Sustainable Plastic Packaging	1035	687	66.4%	15.47
Transforming Construction	1861	657	35.3%	24.42
Transforming Food Production	69	37	53.6%	41.14
Transforming Foundation Industries	219	99	45.2%	3.86

Source: RAND Europe analysis of Dimensions data provided by Digital Science.

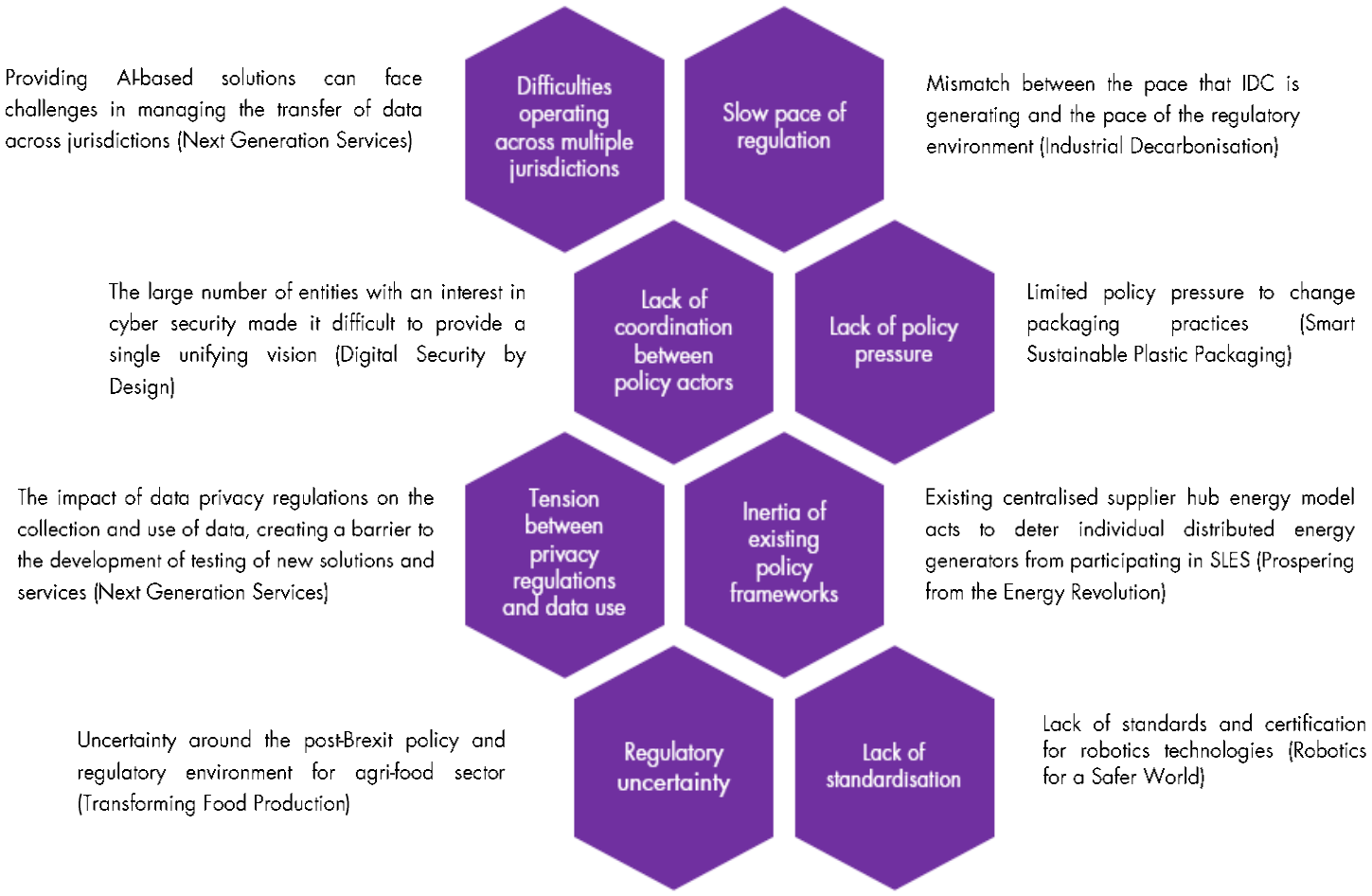
3.4. Policy landscape

Key message: Across Challenge areas, existing policy landscapes presented barriers to the advancement and scale-up of technologies and innovations at baseline.

Evaluation question: To what extent has the ISCF contributed to evidence-based policymaking surrounding the Challenges?

Across Challenge areas, existing policy landscapes presented obstacles to the advancement and scale-up of technologies and innovations at baseline. This has already been noted in Section 3.1.5 above, where in a wide range of reported barriers to the scale-up of innovation was outlined. In Section 3.3, gaps in policymakers' understanding and engagement in the Challenge areas were also considered. In Figure 16, examples of obstacles posed by existing policy landscapes are provided drawing on evidence from baselining workshops and Challenge-level baseline reports. Barriers posed include: difficulties experienced by companies operating across multiple jurisdictions; the slow pace of regulation compared to technological change; lack of coordination between policy actors; lack of policy pressure for change; tensions between privacy regulations and data collection and exchange activities; the inertia of existing policy frameworks; regulatory uncertainty; and a lack of standardisation. As with Figure 9, the examples presented in Figure 16 are intended to be illustrative rather than exhaustive.

Figure 16: Common barriers posed by existing policy landscapes at baseline



4. Capacity and investment

The ISCF aims to increase capacity and investment in R&I in the UK. In addition to public investment, this means ensuring the generation of wider private and overseas funding towards addressing the Challenges and ensuring the skills and physical infrastructure are in place to enable, encourage and capitalise upon that investment. In turn, the Fund aims to contribute to employment and new business creation within the Challenge areas, paving the way for longer-term economic impact. In this chapter, we set out the baseline picture regarding capacity and investment in UK R&I through sections focusing on the following areas:

- **UK businesses investment in R&D:** Providing baseline evidence for the evaluation question: 'To what extent has the ISCF increased UK businesses' investment in R&D?'
- **Overseas investment in UK R&D:** Providing baseline evidence for the evaluation question: 'To what extent has the ISCF increased overseas investment in R&D in the UK?'
- **Wider investment in UK R&D:** Providing baseline evidence for the evaluation question: 'How much additional public and private R&D investment has the ISCF contributed towards the R&D investment target of 2.4 per cent of GDP by 2027?'
- **Riskiness of investment in R&D:** Providing baseline evidence for the evaluation question: 'To what extent has research supported by the ISCF opened up new avenues of investment (de-risking)?'
- **Geographical distribution of investment in R&D:** Providing baseline evidence for the evaluation question: 'While the ISCF is place-agnostic, to what extent have the Fund's investment and activities been widely distributed across the UK?'
- **Skills and capabilities:** Providing baseline evidence for two evaluation questions: 'How and to that extent, has the ISCF increased individual capabilities and capacities both in research and innovation?' and 'To what extent has the ISCF attracted additional talent and Challenge-associated skills into the UK?'
- **Equality, diversity and inclusion:** Providing baseline evidence for the question: 'How has the ISCF contributed to equality, diversity and inclusion?'
- **Jobs and business creation:** Providing baseline evidence for the question: 'To what extent has the ISCF contributed to the creation and retention of new business and high-skilled jobs?'

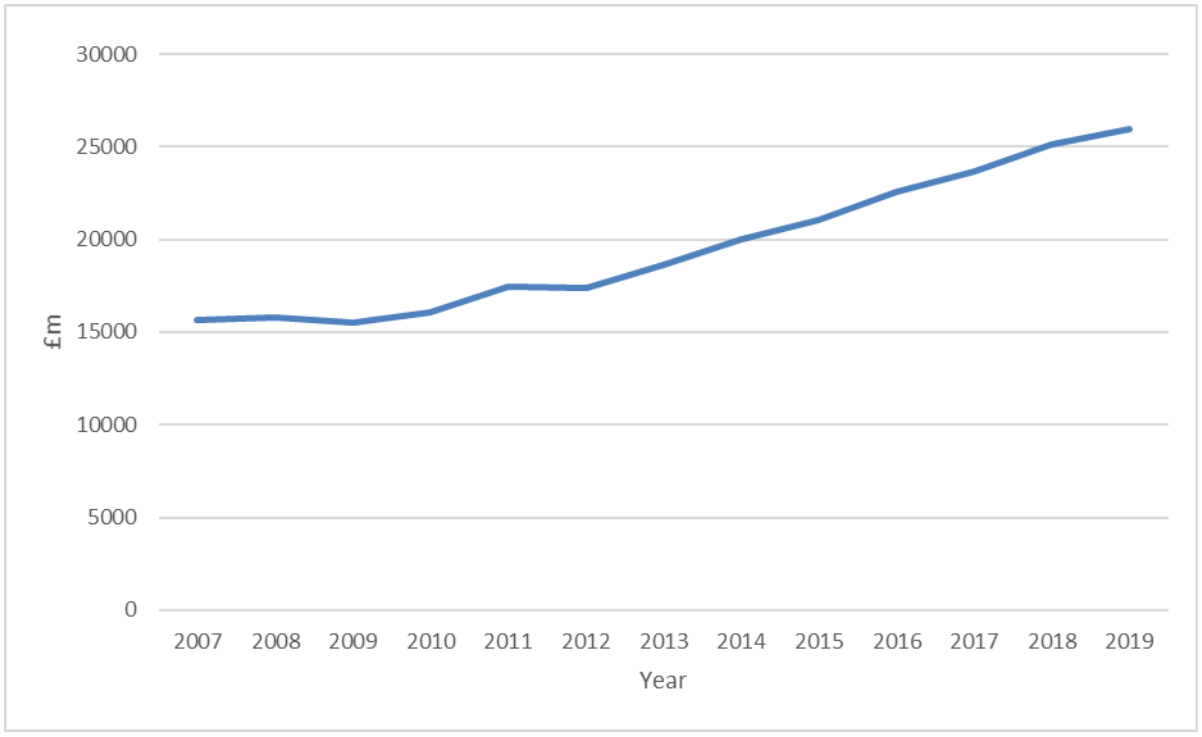
4.1. UK business investment in R&D

Evaluation question: To what extent has the ISCF increased UK businesses' investment in R&D?

Key message: Firms in the UK had some experience funding and delivering R&D projects. However, there was considerable variation between sectors, with some featuring high-performing and/or well-established firms with high levels of R&D expenditure, while others had more limited prior R&D investment.

At baseline, UK businesses invested almost £26bn in R&D (Figure 17), but levels of investment varied across sectors. Data from 2019 shows that current and capital expenditure on R&D performed in UK businesses varied across sectors of relevance to the ISCF Challenges (see Table 4). Sectors with higher levels of expenditure included: pharmaceuticals, motor vehicles and parts, computer programming and information service activities, aerospace and software development. Those with lower amounts of expenditure included: pulp, paper and paper products and casting of iron and steel.

Figure 17: Gross domestic expenditure on R&D by UK businesses (2007–2019)



Source: RAND Europe analysis of ONS data

Table 4: Current and capital expenditure on R&D performed by UK businesses (detailed product groups, 2019) in £ million (ISCF Challenge-relevant sectors only)

	Total	Capital Total	Current Total	Salaries and wages	Other current
TOTAL	25,948	2,321	23,627	12,740	10,887
Pharmaceuticals	4,772	345	4,427	2,021	2,407
Motor vehicles and parts	3,415	322	3,093	1,325	1,768
Computer programming and information service activities	1,945	389	1,556	714	842
Aerospace	1,679	108	1,571	907	664
Software development	1,647	54	1,593	1,217	375
Research and development services	1,387	74	1,314	776	538
Chemicals and chemical products	909	154	755	411	344
Computers and peripheral equipment	491	56	435	261	174
Food products and beverages; Tobacco products	445	23	422	232	190
Construction	417	43	374	247	127
Other manufactured goods	258	10	247	149	98
Fabricated metal products except machinery and equipment	214	27	186	111	75
Rubber and plastic products	188	4	184	54	130
Extractive Industries	155	1	153	71	82
Agriculture, hunting and forestry; Fishing	144	14	131	42	88
Refined petroleum products and coke oven products	136	6	130	51	79
Electricity, gas and water supply; Waste management	136	45	92	48	43
Other non-metallic mineral products	103	3	100	52	48
Pulp, paper and paper products; Printing; Wood and straw products	92	30	62	34	27
Non-ferrous metals	67	14	53	39	14
Transport and storage, incl. postal and courier activities	66	-	66	58	8
Casting of iron and steel	42	-	42	12	30

Source: RAND Europe analysis of ONS data

Firms supported by the ISCF had some prior experience funding and delivering R&D projects, though again the evidence suggests that investment varied across sectors. In the Faraday Battery Challenge, for example, supported firms had, on average, five ongoing R&D projects of which two related to the Challenge.[73] For Medicines Manufacturing, successful collaborative research and development (CR&D) applicants were involved in an average of four R&D projects at the time of application and medicines manufacturing R&D accounted for around half of their R&D spending and employment.[74]

Across the Challenges, ISCF award-holding firms appear to have spent vastly different amounts on R&D prior to the ISCF. In the Next Generation Services Challenge, for example, more than half of award-holding firms invested less than £50,000 overall in AI and data applications R&D at baseline, [75] while in Future Flight, two-thirds (65 per cent) of business respondents spent up to £1m on all R&D activities prior to the

[73] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

[74] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report.'

[75] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft'.

Challenge.[76] Differences in R&D spending at baseline may reflect not just the different company sizes, but also differing prevalence of R&D across sectors, or perceived opportunity for exploitation of a new market. Lower levels of R&D investment among Next Generation Services firms, for example, reflect historically lower trends of R&D investment within the legal, accounting and financial services sectors compared to other more R&D-intensive business sectors.

In some sectors, business R&D expenditure was concentrated within a small number of high-performing and/or well-established firms. For example, in the Industrial Decarbonisation Challenge, (69 per cent) of businesses had zero decarbonisation R&D expenditure, so median expenditure on R&D related to decarbonisation was £0.[77] However, the mean was £150,000, pointing towards high levels of R&D expenditure among a select few firms.[78] Similarly, in the Future Flight Challenge, two thirds (65 per cent) of business respondents spent up to £1m on all R&D activities in the financial year 2019/2020 and 8 per cent spent upwards of £50m on R&D activities.[79] Similar evidence was available from the Medicines Manufacturing, Audience of the Future and Transforming Foundation Industries Challenges. However, it should be noted that the costs of conducting R&D vary significantly between these different areas, which may be partly reflected in the level of R&D spend. Table 5 presents more information on levels of R&D investment by Challenge-relevant firms at baseline.

Table 5: Key findings on R&D investment of Challenge-relevant businesses at baseline

Challenge	Key findings on R&D investment of Challenge-relevant businesses
Medicines Manufacturing[80]	• Successful CR&D applicants were involved in an average of four R&D projects at the time of application to Medicines Manufacturing, with medicines manufacturing R&D accounting for around half of their R&D spending and employment. Successful CR&D applicants had a median of nine R&D workers against a median total employment of 41. • DHTC applicants were highly R&D-intensive, with an average of four workers out of five in R&D occupations.
Data to Early Diagnosis and Precision Medicine[81]	• At baseline, nine out of 10 precision medicine firms (91%) reported having invested in R&D in the last three years. The proportion of firms investing in R&D was similar across technology areas, ranging from 96% in genomics to 91% in AI technologies. • Around two thirds of precision medicine firms (64%) stated that the amount of R&D they undertook in the past three years (2018–21) was higher than in the previous three-year period (2015–18).

[76] Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report.'

[77] Ipsos MORI, 'Industrial Decarbonisation Challenge - Baseline Report.'

[78] Ipsos MORI.

[79] Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report.'

[80] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report.'

[81] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report.'

Audience of the Future[82]	• Within the Creative Immersive sector, successful ISCF applicant firms spent on average (median) £70,000 on R&D (£30,000, median for unsuccessful firms), and invested £30,000 in immersive content or technologies (around £15,000 median for unsuccessful firms).
Robotics for a Safer World[83]	• For ISCF specific firms, successful and unsuccessful firms were comparable in levels of R&D activity at the point of application with no statistically significant difference in means or medians.
Next Generation Services[84]	• Just over half of applicant companies (successful and unsuccessful) had delivered R&D projects prior to the programme, though unsuccessful applicants were more likely to have delivered R&D projects in relevant sectors. • Among successful applicants, more than half invested less than £50k overall in AI and data applications R&D, while another 40% invested £50–500k.
Quantum Technologies[85]	• Prior to the Quantum Technologies Challenge, award-holding businesses had spent on average (median) c.£283k on R&D, c.£37k of which was dedicated to the development of quantum technologies. Average (median) spend on R&D for unsuccessful applicants was £75k.
Prospering from the Energy Revolution[86]	• For Prospering from the Energy Revolution Demonstrator projects, few firms reported prior investments in the novel technologies being developed, with total investment across all projects equalling £1.8m. • Fast Start project applicants had spent on average £151,000 on their projects at the point of application. • Successful Concept and Future Designs applicants had spent on average £59,000 on their projects at the point of application (£107,000 for unsuccessful applicants). • For Detailed Designs, successful applicants had spent £37,000 on average (£49,000 for unsuccessful applicants). • For Key Technology Components, successful applicants had spent £108,000 on average (£81,000 for unsuccessful applicants).
Industrial Decarbonisation[87]	• Companies that did provide information on baseline data on investments in R&D for decarbonisation technologies and projects were relatively R&D-intensive. Of the three Industrial Decarbonisation Challenge industry partners who returned relevant information, from an annual turnover of £64.5bn, they invested an estimated £302.2m in R&D, of which £59.8m was in decarbonisation. • Outside the Industrial Decarbonisation Challenge, only 17% of wider businesses surveyed had current R&D programmes related to decarbonising manufacturing processes – of these, 9% had just one such programme. Most businesses (69%) had zero R&D expenditure in this area.

[82] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report.'

[83] Technopolis Group and Ipsos MORI, 'ISCF Robotics and Artificial Intelligence in Extreme Environments - Baseline and Process Evaluation Report.'

[84] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[85] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report.'

[86] Ipsos MORI and Technopolis Group, 'Industrial Strategy Challenge Fund: Prospering from the Energy Revolution - Evaluation Baseline Report.'

[87] Ipsos MORI, 'Industrial Decarbonisation Challenge - Baseline Report.'

Faraday Battery[88]	• At baseline, successful applicants had spent a mean of £2.5m and a median of £0.3m on battery R&D. They also had around five ongoing R&D projects, of which two related to batteries. Across these fields, successful applicants demonstrated a higher rate of R&D activity than unsuccessful applicants (mean R&D spent: £0.7m; median R&D spend £0.025m; median number of ongoing battery R&D projects: 1)
Future Flight[89]	• At baseline, 38% of applicant firms spent at least £500,000 on R&D activities, and two thirds (65%) spent up to £1m on R&D activities in the financial year 2019/2020. An additional quarter (27%) spent more than £1m, with 8% spending upwards of £50m and an additional 9% spending £10m or more. • A small proportion of firms (8%) spent nothing at all on R&D in 2019/2020.
Smart Sustainable Plastic Packaging[90]	• Sector-level R&D investment associated with the SSPP Challenge amounted to £15m in 2018, or 0.2% of total sector-level GDP.
Transforming Construction[91]	• Most (59%) award-holding ISCF firms invested less than £500,000 in R&D in the year prior to engagement in the Transforming Construction Challenge. Of the firms that did invest, over half (54%) invested between £100,000 and £250,000. • The other two largest clusters were those spending more than £5m (14%) and those that did not know their level of investment in R&D prior to TCC engagement (18%).
Transforming Foundation Industries[92]	• Across the Transforming Foundation Industries sectors, just over half of businesses had invested in R&D and/or innovation in the financial year 2019/2020. While a majority of SMEs invested in R&D, most micro-businesses (businesses that have a total of nine or fewer employees), which made up a majority of the sample, had not invested in R&D. • Of those businesses that did invest in R&D, almost three quarters (74%) invested less than £250k and around two fifths (38%) invested less than £50k. • Of all sectors, the chemicals sector had the highest percentage of businesses investing in R&D (nearly three quarters) and spending in R&D both in absolute terms and as a proportion of gross value added (GVA). However, unlike other foundation industry sectors, which all increased their R&D spend from 2014–19, the chemicals sector has shown no clear trend in this regard.
Transforming Food Production[93]	• According to a baseline survey, 91% of successful applicants to the Transforming Food Production Challenge had made investments in R&D for the purposes of current or future innovation in the three years prior to applying to the Challenge (73% for unsuccessful applicants), with 57% reporting extensive prior experience of R&D in relation to the agri-food sector (43% for unsuccessful applicants).
Self Driving Vehicles[94]	• In 2018, UK government funding for connected autonomous vehicle (CAV) projects was supported by £68m from industry, supporting over 70 projects.

[88] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

[89] Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report.'

[90] Eunomia, 'Smart Sustainable Plastic Packaging Challenge Evaluation - Final Baseline Study.'

[91] Frontier Economics, 'Transforming Construction Challenge - Baseline Report.'

[92] SQW, 'Transforming Foundation Industries: Industrial Strategy Challenge Fund Evaluation - Baseline Report.'

[93] SQW, 'Transforming Food Production Evaluation - Baseline: Overview Report.'

[94] Adroit Economics Ltd., 'Autonomous Vehicles,' Market Analysis, 2018.

Creative Industries Clusters	• A baseline survey found that a majority of cluster businesses (7/10) were intending to increase their investment in data- or technology-driven applied research within the next 12 months.

Source: RAND Europe analysis of Challenge-level baseline reports and market analysis reports

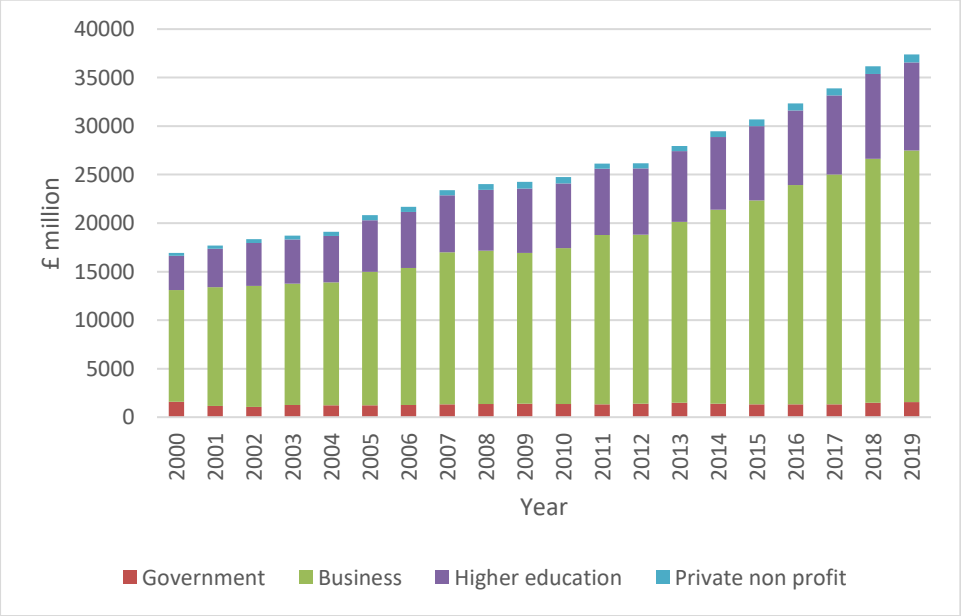
4.2. Overseas investment in UK R&D

Evaluation question: To what extent has the ISCF increased overseas investment in R&D in the UK?

Key message: At baseline, there was evidence of overseas R&D investment in UK businesses across many sectors. Foreign direct investment was particularly important within certain Challenge areas, including the life sciences sector and for the chemicals, ceramics and metals sectors.

There was evidence of overseas investment in R&D within UK businesses at baseline, with variations across sectors. Table 6 presents expenditure on R&D in the UK by performing and funding sectors in 2019. As this shows, in 2018, overseas investment in UK R&D totalled £5.06bn, with the largest proportion of this (£3.25bn) spent on R&D in business enterprises. This reflects a trend towards growth in R&D conducted, particularly in the business enterprise sector as shown in Figure 18. Table 7 presents the number of foreign direct investment (FDI) projects in the UK across different sectors relevant to ISCF Challenges in 2018/19.[95] Sectors with a high number of FDI projects at baseline included software and

[95] FDI projects as presented in Figure 18: GERD by sector of performance (2000–2019)



Source: RAND Europe analysis of ONS data

Table 7 do not necessarily equate to investments in R&I specifically but can help to illustrate broader levels of overseas investment activity within specific sectors.

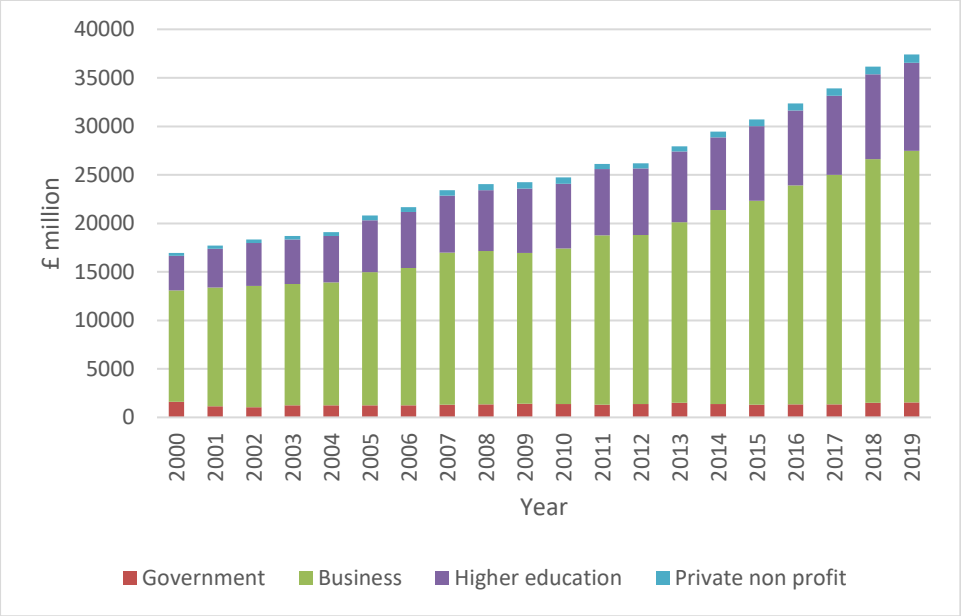
computer services, business and consumer services, financial services and environment, infrastructure and transportation.

Table 6: Expenditure on R&D in the UK by performing and funding sectors (2018) (£ million)

		Sector performing the R&D				
		Government UKRI	Higher Education	Business Enterprise	Private Non-Profit	Total
Sector funding the R&D	Government	1,446	380	1,190	113	3,129
	UKRI	677	2,600	530	189	3,996
	Higher Education Funding Councils	-	2,492	-	-	2,492
	Higher Education	22	-	179	10	211
	Business Enterprise	70	389	19,832	25	20,315
	Private Non-Profit	72	1,318	67	402	1,860
	Overseas	172	1,562	3,250	84	5,069

Source: RAND Europe analysis of ONS data

Figure 18: GERD by sector of performance (2000–2019)



Source: RAND Europe analysis of ONS data

Table 7: Sector breakdown for all FDI[96] projects (2018/19) (ISCF Challenge-relevant sectors only)

Sector	No. of FDI Projects
Software and computer services	366
Business and consumer services	155
Financial services	148
Environment, infrastructure and transportation	142
Advanced engineering and supply chain	130
Food and drink	115
Life sciences	115
Creative and media	111
Wholesale	102
Automotive	93
Electronics and communications	85
Biotechnology and pharmaceuticals	53
Chemicals and agriculture	43
Aerospace	42
Extraction industries	41
Renewable energy	41
Total	1,782

Source: Department for International Trade

There was some evidence of overseas investment in UK businesses within Challenge areas, including FDI. For example, at baseline, several firms in the advanced therapy medicinal products (ATMP) sector had recently been acquired by overseas investors.[97] Overseas corporates had some interest in UK energy storage businesses.[98] Five UK businesses operating in batteries and electric vehicles (EVs) were acquired between 2012 and 2018.[99] Of foundation industry companies that invested in R&D and/or innovation at baseline, less than 10 per cent involved foreign direct investment.[100] However, for a small proportion of companies in chemicals, ceramics and metals (7 per cent each), FDI played an important role in R&D investment, with between 75 per cent and 100 per cent of their investment coming from FDI.[101] FDI contributed sizeably to petroleum, chemicals, pharmaceuticals, rubber and plastic products, where it

[96] Foreign Direct Investment is a type of cross-border investment in which an investor resident in one economy establishes a lasting interest in, and a significant degree of influence over, an enterprise resident in another economy OECD iLibrary, 'Foreign Direct Investment (FDI)' n.d., https://www.oecd-ilibrary.org/finance-and-investment/foreign-direct-investment-fdi/indicator-group/english_9a523b18-en.

[97] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report.'

[98] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

[99] Ipsos MORI et al.

[100] SQW, 'Transforming Foundation Industries: Industrial Strategy Challenge Fund Evaluation - Baseline Report.'

[101] SQW.

accounted for between 10 per cent to 16 per cent of GVA produced in those sectors over 2016–19.[102] In 2018, total FDI in petroleum, pharmaceuticals, rubber and plastic products was £63m.[103]

[102] SQW.

[103] Eunomia, 'Smart Sustainable Plastic Packaging Challenge Evaluation - Final Baseline Study.'

4.3. Wider investment in UK R&D and businesses

Evaluation question: How much additional public and private R&D investment has the ISCF contributed towards the R&D investment target of 2.4 per cent of GDP by 2027?

Key message: In 2018, overall expenditure on R&D in the UK was at £37.1bn, which represented 1.71 per cent of GDP. Wider investment in UK R&D and businesses varied considerably between sectors. There was some public sector funding, but this lacked coordination and long-term focus. The third sector played an important role in funding medical R&D. Private sector investment in UK businesses varied due to differences in size of different sectors.

4.3.1. UK government investment in R&D

In 2018, overall expenditure on R&D in the UK was at £37.1bn.[104] This included R&D performed and funded by business enterprise, higher education, government, UK Research and Innovation, and private non-profit organisations. Total R&D expenditure in the UK in 2018 represented 1.71 per cent of GDP.[105]

UK government investment in R&D varied between Challenges but overall, it was not co-ordinated and lacked a long-term focus. The ISCF has not been established in an empty landscape and there were pockets of public funding and innovation happening across Challenge areas.[106] Some industries had systemic support for R&I, e.g. aerospace (ATI).[107] Government funding for technology in those areas also brought big players in as partners and helped to create a route to market for innovation. Prior to the launch of the Prospering from the Energy Revolution Challenge, the UK was one of the few countries that had provided government funding to pilot SLES designs.[108] Public funding appeared to be fairly strong in the quantum technologies sector – for both successful and unsuccessful applicants to the Quantum Technologies Challenge, the majority of R&D funding was sourced by UK public funding sources (74 per cent).[109] Prior to the Quantum Technologies Challenge, successful applicant research groups and institutes had obtained on average (median) £300,000 from grant funding and other sources (substantially lower than unsuccessful applicants, for whom the average was c.£3.5m).[110] In 2018, prior to the establishment of the Self Driving Vehicles programme, UK government funding in connected and autonomous vehicles (CAV) projects was reported to be £120m, supporting over 70 projects.[111]

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[104] ONS, 'Gross Domestic Expenditure on Research and Development, UK: 2018,' 2018, https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgrossdomesticexpenditureonresearchanddevelopment/2018.

[105] ONS.

[106] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[107] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[108] Ipsos MORI and Technopolis Group, 'Industrial Strategy Challenge Fund: Prospering from the Energy Revolution - Evaluation Baseline Report.'

[109] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report.'

[110] Technopolis Group.

[111] Adroit Economics Ltd., 'Autonomous Vehicles.'

By contrast, other Challenge areas had less well-established government spending. In the Next Generation Services Challenge, some award-holding firms explicitly noted that they had previously struggled to find suitable public funding, while for others, the ISCF will represent a step-change in public investment.[112] For the Audience of the Future Challenge, private investment in the sector was six times higher in comparison with public support to R&D over the previous three years, pointing to limited public investment.[113] Meanwhile, evidence on investment activity within Creative Clusters suggested that a significant proportion of Cluster businesses were uninformed or struggled to access public funding.[114] In the health and healthcare sector, there were few public funding opportunities, for example for AI and data-driven developments.[115] However, funders such as IUK had also been funding commercial organisations in the area of health and healthcare data for a while.[116] For example, the 100,000 Genomes project was a major funding push in the 2010s.[117]

In some Challenge areas, there was evidence that public investment in R&D was increasing at baseline. For example, prior to the Faraday Battery Challenge, public support for battery R&D from the UK government had steadily increased over time, primarily via the Engineering and Physical Sciences Research Council (EPSRC) and IUK, with spending of almost £30m in 2016.[118] Similarly, within the Transforming Food Production Challenge, baseline data showed an upward trend in the number of grants awarded within the agricultural sector since 2011, with £104m of funding awarded to high-growth firms in aggregate to the sector (through 681 grants).[119]

4.3.2. Third sector investment in R&D

The third sector played an important role in funding medical R&D. At baseline, medical research charities played an important role in funding research in the UK.[120] According to the Association of Medical Research Charities, in 2018 their members funded 41 per cent of publicly funded research nationally, to the value of £1.3bn.[121] Three of the biggest charity research funders are Cancer Research UK (CRUK), Wellcome and the British Heart Foundation (BHF).[122] Third sector investment was not identified as a key source in other sectors.

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[112] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[113] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report.'

[114] Frontier Economics and BOP Consulting, 'Evaluation of the Creative Industries Clusters Programme - Phase 2 Baseline and Initial Impact Reporting - the CRPDs.'

[115] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[116] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[117] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[118] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

[119] SQW, 'Transforming Food Production Evaluation - Baseline: Overview Report.'

[120] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report.'

[121] SQW.

[122] SQW.

4.3.3. Private investment in UK businesses

Unsurprisingly, given the different sizes of the sectors and their vastly different contributions to UK GDP as a whole, baseline private investment in UK businesses varied across sectors. For example, within the services sector, the insurance industry alone raised £65bn in private investment in 2017/18[123], while for the entire creative services sector, £291m was raised between 2017 and 2020.[124] Table 8 presents key findings on private investment in UK businesses within Challenge areas at baseline, as derived from Challenge-level baseline reports and market analysis reports.

Table 8: Key findings on private investment in Challenge-relevant businesses at baseline

Challenge	Key findings on private investment in Challenge-relevant businesses
Medicines Manufacturing[125]	• At baseline, 41% of successful applicants had secured external equity investment. • Firms involved in ATMP raised £0.7m in capital in 2018, but this was mainly driven by a small number of companies.
Audience of the Future[126]	• The overall amount of private investment in the UK creative immersive content sector between 2017 and 2020 was £291m (likely an underestimate given certain non-disclosures).
Next Generation Services[127]	• Over the 2017–18 period, the insurance industry raised £65bn in additional investment, compared to the legal sector which raised £50bn in capital with a further £10.5bn in additional funding, and the accounting sector, which attracted around £5.5bn in additional investment.
Quantum Technologies[128]	• Around 25% of ISCF participating organisations in the Quantum Technologies Challenge had secured an equity deal in the baseline year, rising to 35% in 2020. For participating organisations, the total value of equity deals peaked at £160m in 2020, rising from £59m in 2017.
Prospering from the Energy Revolution[129]	• Only 27 of 172 of successful applicant firms (16%) supported by the Prospering from the Energy Revolution Challenge had raised external equity funding at the time of their award. The firms concerned had raised a total of £87m in venture funding, predominantly from VC funds, and tended to display more extensive fundraising histories than the comparison group of unsuccessful applicants.
Faraday Battery[130]	• Despite a 2010–17 decrease in net capital expenditure, venture capital and private equity investment flows into UK-headquartered firms operating in the energy storage sector increased from £24.7m to £87.3m between 2012 and 2018. However, investment in 2018 was largely driven by one firm.

[123] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[124] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report.'

[125] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report.'

[126] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report.'

[127] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[128] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report.'

[129] Ipsos MORI and Technopolis Group, 'Industrial Strategy Challenge Fund: Prospering from the Energy Revolution - Evaluation Baseline Report.'

[130] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

Transforming Food Production[131]	• Relatively few successful applicants (14%) to the Transforming Food Production Challenge had experience of securing shared equity or loan finance prior to their application (11% for unsuccessful applicants).
Self Driving Vehicles[132]	• Data from the British Venture Capital Association report a total £4.4bn of private equity and venture capital investment in sectors relevant to autonomous vehicles between 2011 and 2016, spanning investment in 1260 companies.
Creative Industries Clusters[133]	• A low proportion (one in 10) of businesses participating in the Creative Industries Clusters Programme considered themselves well-informed or able to access private (or public) finance at baseline.

Source: RAND Europe analysis of Challenge-level baseline reports and market analysis reports

4.4. Riskiness of investment in R&D

Evaluation question: To what extent has research supported by the ISCF opened up new avenues of investment (de-risking)?

Key message: At baseline, investment in R&I across several sectors was considered high-risk, with inadequate mechanisms to support investment, adoption and scale-up.

Several sub-sectors within different Challenge areas were regarded as high-risk at baseline, particularly due to lack of support mechanisms for accelerating innovation, adoption and scale-up. In the area of AI for healthcare specifically, investment was regarded as high-risk at baseline.[134] This was driven by a lack of public support for R&D and a fragmented funding environment, but also a lack of infrastructure to support access to data.[135] For example, in terms of data and digital innovation there was generally poor infrastructure amongst NHS organisations.[136] Novel therapies and antibiotics were also regarded as high-risk, lacking an obvious market.[137] Across many of the Challenge areas and sub-sectors, the model for de-risking was available but small-scale, and the infrastructure to drive adoption and scale-up was lacking.[138]

For some sub-sectors, there was little incentive for industry to invest in relevant Challenge areas. In 2018, for example, investment in SMR development was risky.[139] Rolls-Royce, one of the leaders of the Low Cost Nuclear Challenge's UKSMR Consortium, would not have continued to develop the SMR project without the funding it received through the Challenge.[140] In 2018, battery technology was considered high-risk,

[131] SQW, 'Transforming Food Production Evaluation - Baseline: Overview Report.'

[132] Adroit Economics Ltd., 'Autonomous Vehicles.'

[133] Frontier Economics and BOP Consulting, 'Evaluation of the Creative Industries Clusters Programme - Phase 2 Baseline and Initial Impact Reporting - the CRPDs.'

[134] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[135] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[136] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[137] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[138] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[139] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[140] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

particularly as it was not a clearly defined area, with lack of recognition within the academic community, as well as a lack of support and strategy within the policy community.[141] This created uncertainty around who industry could approach for questions regarding battery technology transitions, and in particular next generation battery chemistries.[142] There was also no incentive for industry to invest in the Digital Security by Design Challenge area.[143]

Some sectors (e.g. ATI and CCUS) had systemic support for R&I, which helped to bring in industry support and ultimately create a route to market.[144] However, most sub-sectors did not benefit from systematic support, and subsequently encountered challenges in accelerating technology.[145] Therefore, participants across several workshops highlighted that an explicit aim of the ISCF Challenges was to address market failures, where the incentive for an individual company to act was low, but where collective action at a sector level (and with evidence of government support or potential for regulatory change) could be beneficial for all companies.[146]

4.5. Geographical distribution of investment in R&D

Evaluation question: While the ISCF is place-agnostic, to what extent have the Fund's investment and activities been widely distributed across the UK?

Key message: At baseline, there were differences across the UK in terms of R&D expenditure, with an apparent concentration of investment in London and the South East compared to the rest of the UK.

In 2018, there were differences across the UK in terms of R&D expenditure. Across the UK, England had higher R&D spending (£33,039m) than Wales (£798m), Scotland (£2,712m) and Northern Ireland (£715m).[147] Within England, there were also differences between regions, with a higher R&D spending in the South East (£7,089m), East of England (£6,608m) and London (£5,970m), compared to other regions.[148] While normalisation against country and regional population sizes would provide further insight on the equity of the distribution of R&D investment, the general picture would appear to be a concentration

[141] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[142] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[143] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[144] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[145] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[146] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space'; 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'

[147] ONS, 'Business Enterprise Research and Development,' 2020, https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/datasets/ukbusinessenterpriseresearchanddevelopment.

[148] ONS.

of R&D investment in England, and in particular in London and its surrounding areas, compared to the rest of the UK.

Looking at IUK investment specifically, data indicates a similar picture, with differences in R&D expenditure and high levels of investment in London and the South East. At the same time, the West Midlands and South West have also received high levels of IUK investment compared to other UK regions. Data on IUK investment by region is presented in Table 9 below.

Table 9: Innovate UK investment by region,[149] 2018 to 2019

NUTS 1 region	IUK spend financial year 2018/2019 £ million
West Midlands	133
South East	129
London	125
South West	116
East Midlands	99
East of England	82
Yorkshire and The Humber	79
Scotland	57
North West	41
North East	39
Wales	30
Northern Ireland	11

Source: RAND Europe analysis of IUK data

[149] Regional breakdown uses nomenclature of territorial units for statistics levels (NUTS) 1 areas.

4.6. Skills and capabilities

Evaluation questions:

- *To what extent and how has the ISCF increased individual capabilities and capacities both in research and innovation?*
- *To what extent has the ISCF attracted additional talent and Challenge-associated skills into the UK?*

Key message: At baseline, the level of skills and capabilities across sectors varied. Some sectors reported a good level of skills, whereas others faced shortages. In particular, several sectors faced difficulties sourcing the right type of skills, specifically individuals with experience around innovation adoption and uptake. In general, sectors lacked a programme of investment for skills. While some sectors relied on international, in particular EU, talent, this has declined since the UK's exit from the EU. At baseline, most IUK projects reported contributions to the development of new skills or the improvement of existing ones.

At baseline, there was a mixed picture in terms of skills and capabilities across sectors, as well as sub-sectors, with some reporting good levels of skills and others facing challenges. The extent of skills in place to deliver on the Challenges were mixed. Some, such as Faraday Battery and Robotics for a Safer World, report that skills to enable delivery of the Challenges were largely in place – noting, for example, that skills requirements were not affecting the location of business activities, or that actions were already being taken by relevant actors to increase skill levels where there were gaps in the sector.[150]

More broadly, some sectors, such as the health and energy sectors, generally had a good level of talent and skills at baseline. For example, the UK had good talent in AI, with London and Edinburgh seen as vanguards for these areas.[151] There was also already a broad range of talent and skills engaged in nuclear technologies at the time of inception of the Low Cost Nuclear Challenge.[152] It was suggested that the strength of the existing talent and skills base within the nuclear sector, combined with the existence of networks such as the Catapults, puts the UK in a better position to pursue SMR development than some international comparators.[153]

At the same time, some sectors and Challenge areas faced obstacles in sourcing the right level of skills. In the transport sector for example, the UK was on the decline internationally, particularly in skills around electrical engineering in 2018.[154] In healthcare, technology and digital skills being traditionally absent from from standard job descriptions and funding allocations, meant the sector severely lacked skills and talent in

[150] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report'; Technopolis Group and Ipsos MORI, 'ISCF Robotics and Artificial Intelligence in Extreme Environments - Baseline and Process Evaluation Report.'

[151] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[152] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[153] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[154] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

these areas.[155] Several sectors, such as energy and manufacturing, reported challenges in attracting a pipeline of talented young people to the sector.[156] In the CAV sector, there were particular skills gaps in relation engineering at baseline, including electrical engineering, software engineering, system engineering, communication engineering and IT engineering.[157] In the advanced materials sector, there was evidence of a shortage of relevant post-graduate-level skills, with reliance on overseas students.[158] Baselining of the Future Flight Challenge noted significant skills gaps at baseline – including a lack of prior experience in delivering aspects of their planned work among participating business or academics.[159] Around one in four businesses participating in the Creative Industries Clusters Programme faced skills barriers at baseline, with most of these reporting barriers in relation to technical and marketing skills.[160] Baselining of the Industrial Decarbonisation Challenge found that assessing skill levels in the sector – particularly quantitatively – was in itself challenging.[161]

A challenge across several sectors was a lack of skills around deployment and adoption of innovation. In the health sector, there was a lack of skills in delivering and deploying innovation rather than around the development or creation of innovation.[162] Despite lots of activity happening in universities, it was hard to find the right talent around the delivery and uptake of innovation[163], as well as the right academic partners to help SMEs resolve specific technical issues.[164] Figure 20 illustrates the availability of skills across different sectors and Challenge areas.

[155] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[156] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[157] Adroit Economics Ltd., 'Autonomous Vehicles.'

[158] Adroit Economics Ltd., 'Materials for Mobility,' Market Analysis, 2018.

[159] Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report.'

[160] Frontier Economics and BOP Consulting, 'Evaluation of the Creative Industries Clusters Programme - Phase 2 Baseline and Initial Impact Reporting - the CRPDs.'

[161] Ipsos MORI, 'Industrial Decarbonisation Challenge - Baseline Report.'

[162] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[163] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[164] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

Figure 19: Key findings on availability of skills across different Challenge areas at baseline

Source: RAND Europe analysis of Challenge-level baseline reports

Across several sectors, there was no visible programme for investment in skills. Many sectors reported a lack of programmes to support skills development. For example, in the IT sector there was no R&D programme and no programme to support skills development in the demand side sector.[165] This was also the case in the energy sector, with no visible programme for investment in skills.[166] In the transport sector, there was no national battery science programme for PhDs in 2018, which was a major gap.[167] In the

[165] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'

[166] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'

[167] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space'

medicines manufacturing sector, there was a lack of apprenticeships, with academics unaware of careers outside industry.[168]

Some sectors relied on international talent, particularly from the EU, and supply of such talent has declined since the UK's departure from the EU. In 2018, several sectors (e.g. health, IT/data, and transport and space) had a good level of talent available and but relied on talent/skills from Europe and the EU in particular. In some areas, the UK's exit from the EU is perceived by stakeholders to have had a negative impact on the availability of EU and European talent. For example, in the area of AI and data science applied to health, a lot of European talent was previously available to the UK, but this has changed since Brexit, with the sector losing people.[169] In the IT sector, Brexit is seen to have reduced the attractiveness of the UK and that has affected a number of programmes in hiring, with large investments happening in the EU that the UK is now not a part of.[170] The space sector indicated that it was a fast-growing sector that used to fill a lot of its demand for skills and talent from the EU.[171] In 2018, 20 to 25 per cent of the space sector workforce in most places was European, and this has fallen steadily since.[172]

Figure 20 below presents data on the number of IUK projects reporting that their project has resulted in the development of new skills, or the improvement of skills, within the project workforce. The data covers the IUK portfolio excluding projects funded under the ISCF and is based on reporting in PCFs.[173] The figure presents data for projects commencing in 2018 only. As this illustrates, a large number of IUK projects have reported improvements and developments in skills across a wide range of areas. Areas in which skills development has been most commonly reported include technical skills or knowledge, problem - solving, and collaborating and partnering. By comparison, fundraising and leadership were areas where a higher number of projects reported that no change had been experienced.

[168] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'

[169] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'

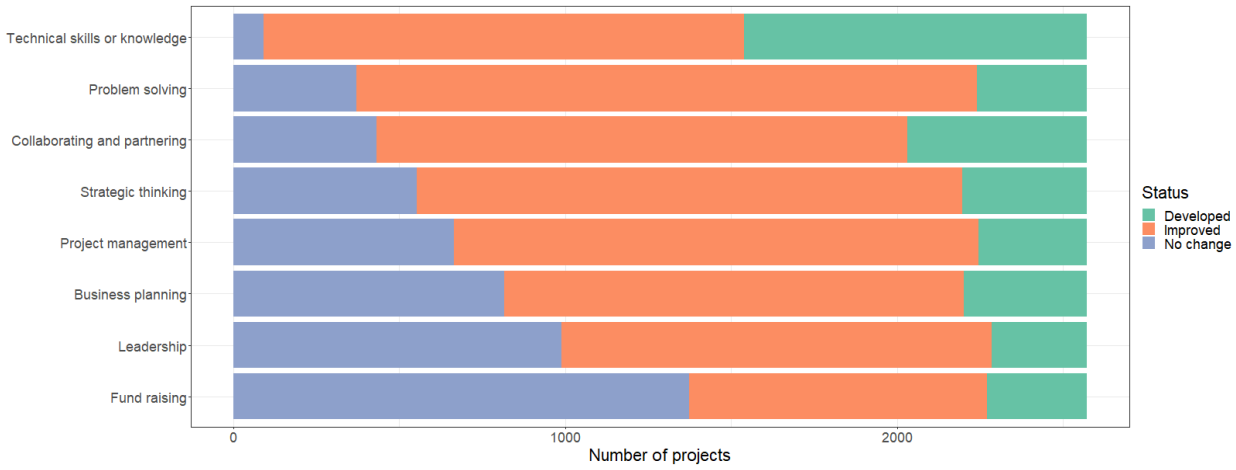
[170] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'

[171] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space'

[172] ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space' 2021

[173] While the data presented here provide a general sense of skills development across IUK projects, it should be noted that data collected through PCFs may be subject to under-reporting.

Figure 20: Number of IUK projects reporting the development of new skills or improvement of existing skills by skill area (2018)



Source: RAND Europe analysis of IUK data

4.7. Infrastructure

Evaluation question: How and to what extent has the ISCF contributed to improved infrastructure to support future R&I investment?

Key message: In 2018, there was a mixed picture in terms of R&I infrastructure across sectors. For some sectors, there were gaps in infrastructure to support R&I and need for further investment. In others, there was some existing R&I infrastructure, but this lacked coordination, and did not support scale-up and adoption.

For several sectors, there was some existing R&I infrastructure, but this was generally not coordinated, did not support scale-up and adoption (e.g. more purposeful utilisation) and there were gaps within different sub-sectors (e.g. accessing data in the health sector). In the health and healthcare sector, there was reasonably advanced research infrastructure around clinical trial performance but in terms of health service data and digital innovation there was generally poor infrastructure amongst NHS organisations.[174] In the health sector, although Catapults and accelerators existed, the infrastructure to drive adoption was not present.[175] This was a similar challenge for the energy sector, in which there were well-developed existing infrastructures in the academic sector (albeit generally at a low TRL) and in national laboratories, but a more purposeful utilisation of the infrastructure was lacking.[176] Similarly, in the food and packaging sub-

[174] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[175] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[176] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

sector, whilst there was a good academic infrastructure for R&I, the infrastructure for scale-up was not there.[177]

Some sectors reported suffering from legacy infrastructure. For example, baselining interviews with stakeholders from the Data to Early Diagnosis and Precision Medicine Challenge identified the challenge of aged infrastructure linked to previous underinvestment, including fragmentation between systems within the NHS, and highlighted the urgent need to connect and facilitate access to high-quality, representative datasets to build capabilities and health data infrastructure.[178] There was also an issue with existing infrastructure in the nuclear sector being relatively siloed with limited linked innovation.[179] In the IT and data workshop, participants indicated that infrastructure to support the work of the Challenges was generally lacking.[180] Similarly, infrastructure around CCUS does not exist at scale and is not expected until 2026.[181]

4.8. Equality, diversity and inclusion

Evaluation question: How has the ISCF contributed to Equality, Diversity and Inclusion?

Key message: At baseline, across most sectors, the lack of diversity in the workforce was emerging as a topic with pockets of activity but, overall, there was a lack of activity and effort behind it.

At baseline, across most sectors, the lack of diversity in the workforce was emerging as a topic with pockets of activity aimed at increasing diversity. For example, according to a baseline survey of the wider sector surrounding the Industrial Decarbonisation Challenge, a majority of business respondents reported that they were taking active steps to promote Equality, Diversity and Inclusion (EDI) with respect to all protected characteristics explored in the survey.[182] Over 70 per cent of respondents agreed their business was taking such action with respect to gender (73 per cent), nationality (71 per cent) and parenthood (71 per cent).[183] By contrast, the fewest businesses agreed that such action was being taken with respect to disability (59 per cent).[184] The main actions businesses were taking to promote EDI was focused on the best person for the role/talent, followed by broad approaches to promoting diversity, and strategy and policy.[185]

[177] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[178] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report.'

[179] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[180] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[181] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[182] Ipsos MORI, 'Industrial Decarbonisation Challenge - Baseline Report.'

[183] Ipsos MORI.

[184] Ipsos MORI.

[185] Ipsos MORI.

The use of specific targets or quotas was less common, with only 2 per cent of respondents reporting that such measures were being introduced.[186]

Overall, however, there was a lack of activity and effort in this area. In 2018, EDI was not being discussed in the AI sector, although concerns around lack of transparency of algorithms were present.[187] In the area of robotics, the skills and human capital challenge was considered significant and it was hard to source any talent, let alone consider EDI.[188] Analysis of the workforce in sectors relevant to the Creative Industries Clusters Programme showed that clusters characterised by high levels of computer science skills were heavily male-dominated and highly educated, suggesting barriers to workforce diversification.[189]

In some sectors, EDI was being discussed in bigger companies (e.g. CCUS) and in academia (e.g. medicines) but there was less focus in SMEs.[190] Moreover, in some cases, where EDI was being discussed, it was focused on certain topics, for example around women, but wider diversity issues were not being talked about.[191] For example, the Athena Swan set of criteria had been developed, and did appear to have a significant effect around raising awareness of the role of women in science within academic institutions.[192] However, across most sectors there was no active promotion of EDI through public investment.[193]

Our picture of EDI within the Fund is limited at present but there is significant ongoing work that will provide useful context for further comparison. This includes an externally commissioned piece of research using secondary data sources looking at EDI across 50 organisations representative of the ISCF portfolio; a pilot survey-based analysis of the diversity within ISCF-funded projects; and a sector-based analysis of the diversity of industries interacting with IUK. We will use these data as part of our wider analysis of EDI to be conducted later in the study.

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[186] Ipsos MORI.

[187] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[188] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[189] Frontier Economics and BOP Consulting, 'Evaluation of the Creative Industries Clusters Programme - Phase 2 Baseline and Initial Impact Reporting - the CRPDs.'

[190] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[191] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[192] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[193] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

4.9. Job and business creation

Evaluation question: To what extent has the ISCF contributed to the creation and retention of new business and high-skilled jobs?

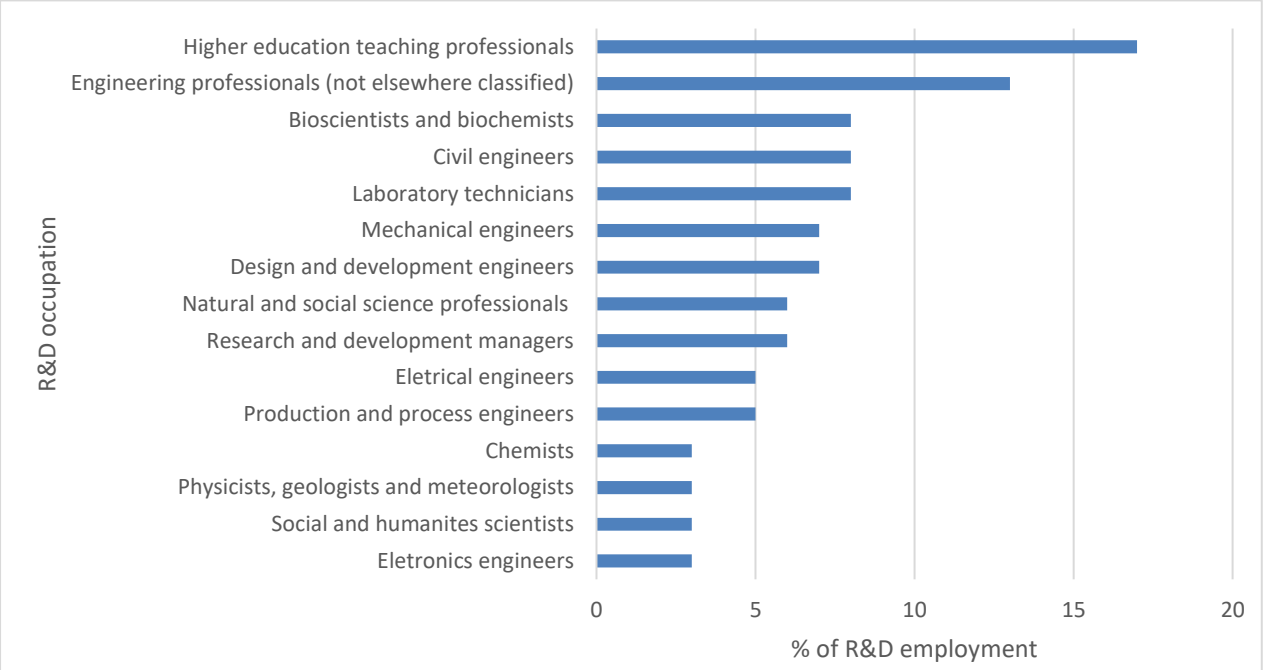
Key message: At baseline, there was a general trend of increasing employment in R&D, with most UK R&D workers employed in higher education and engineering professions and within the public sector and the manufacturing sector. With respect to employment more generally, there was considerable business and job creation in some sectors and sub-sectors, with several others at a turning point. Across several Challenge areas, a strong unmet demand for employment was noted. In some sectors, there was considerable activity happening in terms of the creation of spin-outs.

At baseline, there was a general trend of increasing employment in R&D over time, with R&D occupations representing an increasing share of overall employment. In 2019, there were an estimated 1,026,000 R&D workers in the UK, an increase of 49.5 per cent from 2001.[194] The proportion of overall workers in R&D occupations in 2019 was approximately 3.4 per cent.[195] Figure 21 shows employment of R&D workers by occupation using combined data from the years 2017–2019. This shows that higher education teaching and engineering professionals accounted for the highest share of R&D employment at baseline. Figure 22 shows employment of R&D workers by industrial sector in 2019, focusing on ISCF Challenge-relevant sectors. This shows that the largest share of R&D workers are employed in the public sector and the manufacturing sector.

[194] Warwick Institute of Employment Research, 'The R&D Pipeline: Report to the Department for Business, Energy and Industrial Strategy by the Warwick Institute for Employment Research,' BEIS Research Paper Number: 2021/22, 2020.

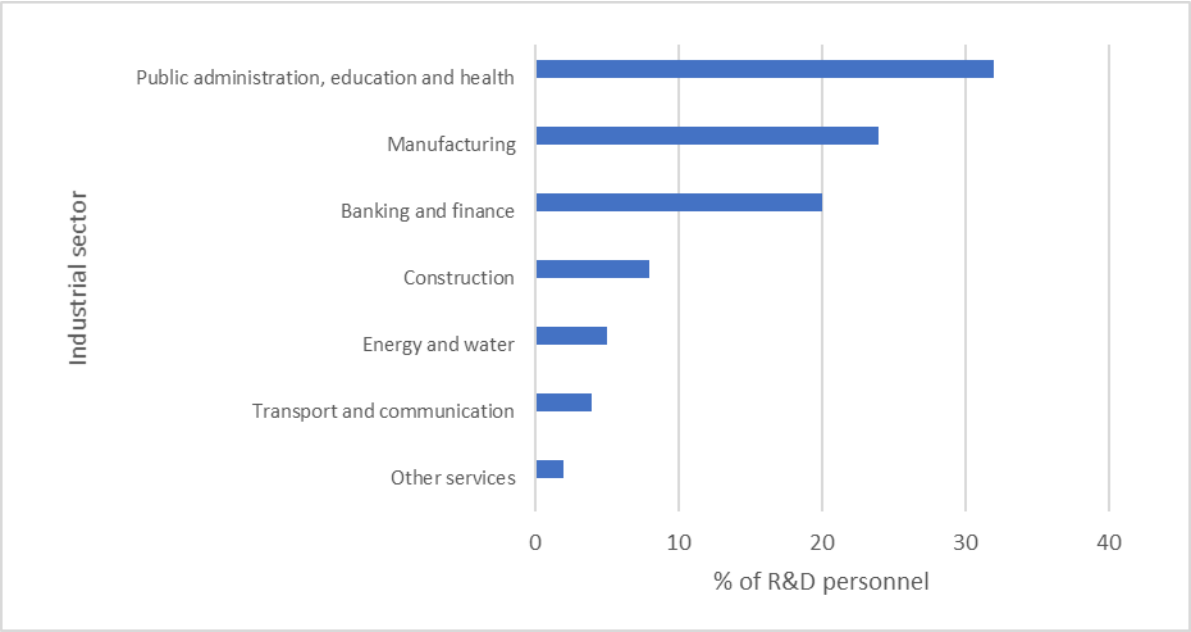
[195] Warwick Institute of Employment Research.

Figure 21: Employment by 4-digit SIC 2010 R&D occupations (2017–2019)



Source: RAND Europe analysis of Labour Force Survey data

Figure 22: Employment of R&D workers by industrial sector (2017–2019) (ISCF Challenge-relevant sectors only)



Source: RAND Europe analysis of Labour Force Survey data

Looking at employment more generally, there were differences in employment and employment growth between sectors, with greater employment and employment growth in some better-established sectors compared to less well-established sectors. Several Challenges were associated with large sectors that employed hundreds of thousands of staff at baseline. For example, the medical technologies sector alone

employed around 122,000 people in 3,600 businesses.[196] Sectors associated with the Next Generation Services Challenge were even larger employers, as the legal sector alone supported around 552,000 full time employees.[197] Other sectors were decidedly smaller, such as the quantum technologies sector, made up of a workforce of 10,151 people.[198] The size of the Creative Industries Clusters workforce was estimated to be 11,910 at baseline, with 26,881 employed in the wider sector workforce.[199]

Just as employment differed by sectors at baseline, so too did trends in employment growth. Certain Challenges, such as Future Flight, Transforming Foundation Industries and Medicines Manufacturing, had experienced significant growth in employment prior to the ISCF,[200] while others, such as Next Generation Services, Faraday Battery and Industrial Decarbonisation were either stable or declining in employment.[201] The CAV sector and the advanced materials sector employed 108,505 and 19,732 people respectively in 2018.[202]

There was considerable investment and job creation in some sectors and sub-sectors with several others at a turning point. There was significant investment, job creation and recruitment in emerging areas of digital health, cell and gene therapy and AI, with new businesses being created.[203] There was also considerable job creation in the traditional aerospace sector.[204] However, in the manufacturing sector there was a sense that jobs were being created but lacked adequate government support.[205] Conversely, there were limited opportunities in certain energy subsectors, such as SLES.[206] The nuclear sector was at a turning point at the time of inception of the Challenge, with increasing opportunities.[207]

Across several Challenges, a strong unmet demand for skilled employment was noted. Within the Medicines Manufacturing Challenge, employing adequately qualified workers in the UK was a difficulty,[208]

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[196] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report.'

[197] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[198] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report.'

[199] Frontier Economics and BOP Consulting, 'Evaluation of the Creative Industries Clusters Programme - Phase 2 Baseline and Initial Impact Reporting - the CRPDs.'

[200] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report'; Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report'; SQW, 'Transforming Foundation Industries: Industrial Strategy Challenge Fund Evaluation - Baseline Report.'

[201] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report'; Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft'; Ipsos MORI, 'Industrial Decarbonisation Challenge - Baseline Report.'

[202] Adroit Economics Ltd., 'Autonomous Vehicles'; Adroit Economics Ltd., 'Materials for Mobility.'

[203] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[204] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[205] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[206] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[207] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[208] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report.'

while within Audience of the Future recruitment of technical staff was a challenge due to difficulties in offering competitive salaries.[209]

Within the aviation and aerospace sub-sector, there was a strong demand for talent and skills, which were partly sourced from the EU.[210] In the area of robotics, there was a strong unmet need for qualified workers with the right skills.[211]

4.9.1. Business creation

There was a mixed picture across sectors in terms of business creation at baseline. In some sectors, there was considerable business creation activity. Table 10 shows the count of births of new enterprises by industry sectors relevant to ISCF Challenges in 2018. As this illustrates, sectors in which a high number of new enterprises were being established included construction, transport, legal and accounting activities and human health. Trends in the 'top 10' of these sectors are shown in Figure 23, showing flat or declining rates of business births in most of these sectors. Note that 2020 data will likely be significantly affected by the Covid-19 pandemic.

Table 10: Count of births of new enterprises by SIC group (2018) (ISCF Challenge-relevant sectors only)

Standard industrial classification (SIC 2007) code and group	2018
43: Specialised construction activities	28,245
62: Computer programming, consultancy and related activities	23,640
41: Construction of buildings	18,635
49: Land transport and transport via pipelines	12,365
71: Architectural and engineering activities; technical testing and analysis	11,350
69: Legal and accounting activities	7,515
86: Human health activities	6,110
93: Sports activities and amusement and recreation activities	4,660
59: Motion picture, video and television programme production, sound recording and music publishing activities	4,005
90: Creative, arts and entertainment activities	3,025
66: Activities auxiliary to financial services and insurance activities	3,020
25: Manufacture of fabricated metal products, except machinery and equipment	2,825
88: Social work activities without accommodation	2,795
64: Financial service activities, except insurance and pension funding	2,420
63: Information service activities	1,835
80: Security and investigation activities	1,600
32: Other manufacturing	1,270
10: Manufacture of food products	1,085
18: Printing and reproduction of recorded media	970
35: Electricity, gas, steam and air conditioning supply	900
87: Residential care activities	865
72: Scientific research and development	800
38: Waste collection, treatment and disposal activities; materials recovery	700

[209] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report.'

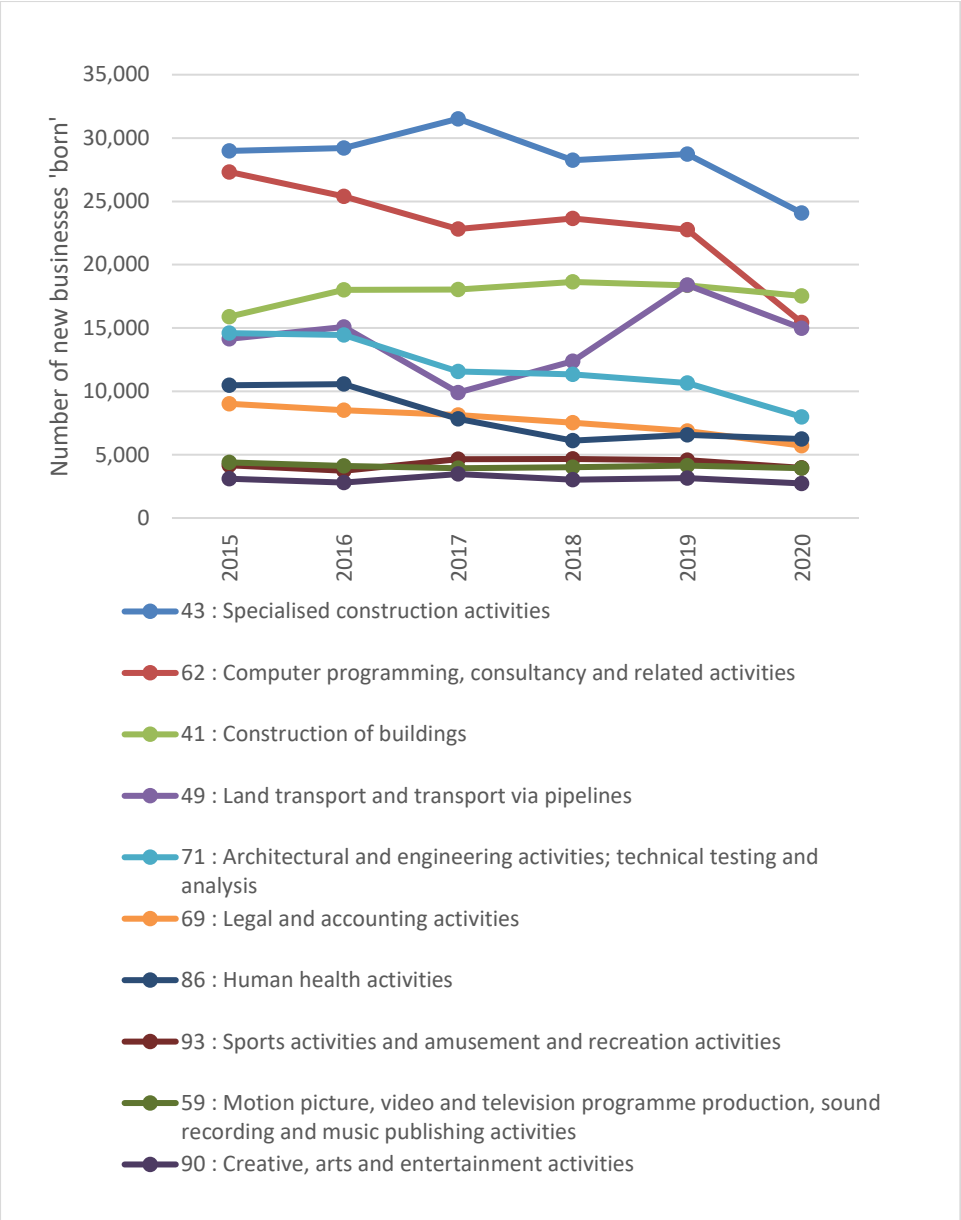
[210] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[211] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

28: Manufacture of machinery and equipment (not elsewhere classified)	610
29: Manufacture of motor vehicles, trailers and semi-trailers	530
30: Manufacture of other transport equipment	350
22: Manufacture of rubber and plastic products	325
65: Insurance, reinsurance and pension funding, except compulsory social security	315
20: Manufacture of chemicals and chemical products	300
51: Air transport	290
23: Manufacture of other non-metallic mineral products	280
24: Manufacture of basic metals	240
60: Programming and broadcasting activities	235
39: Remediation activities and other waste management services	195
17: Manufacture of paper and paper products	120
91: Libraries, archives, museums and other cultural activities	105
21: Manufacture of basic pharmaceutical products and pharmaceutical preparations	100
08: Other mining and quarrying	85
09: Mining support service activities	80
06: Extraction of crude petroleum and natural gas	60
19: Manufacture of coke and refined petroleum products	25
07: Mining of metal ores	15

Source: RAND Europe analysis of ONS data

Figure 23: Trends over time in births of new enterprises by SIC group (top 10 by highest number of new businesses in 2018 amongst ISCF Challenge-relevant sectors)



Source: RAND Europe analysis of ONS data

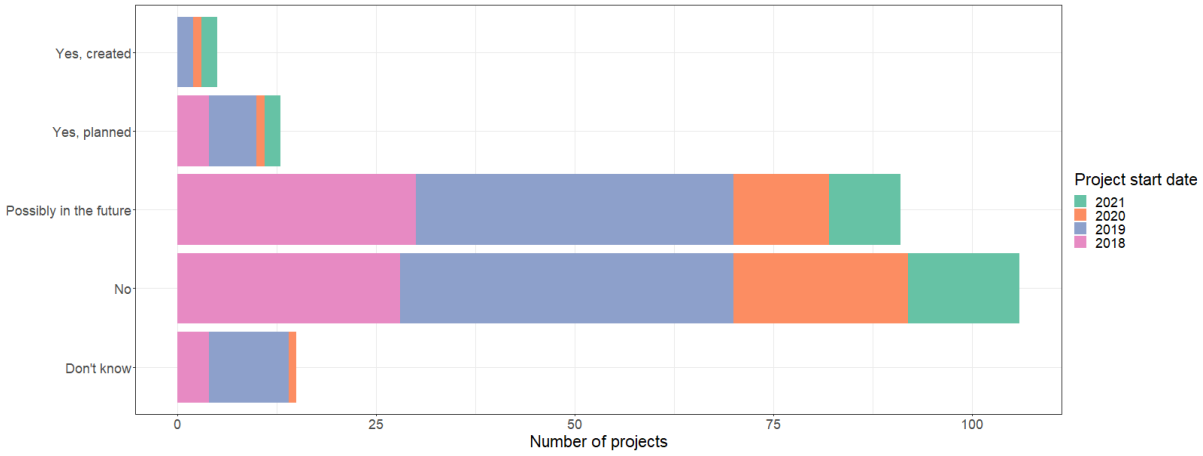
Baselining workshops highlighted that there were several emerging areas of R&I with increasing early-stage activity with businesses and spin-outs being created. This included the health and healthcare sector, particularly within the areas of AI, HMP and cell and gene therapy.[212] In the transport and manufacturing sectors, there was also reported to be considerable businesses creation as part of the development of new technology, though this typically lacked government support.[213]

[212] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[213] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

Figure 24 and Figure 25 present data on the number of IUK projects reporting plans to create spin-outs at baseline. Figure 24 presents the number of IUK projects reporting that involvement in a project had increased the possibility of an academic spin-out being formed. Figure 25 presents the number of projects reporting plans to exploit a product, service or process through the creation of a spin-out (compared against other means of exploitation). The data covers the IUK portfolio excluding projects funded under the ISCF and is based on reporting in PCFs.[214] Figure 24 illustrates that, for most IUK projects commencing in 2018, 2019, 2020 and 2021, project involvement had either not increased the possibility of an academic spin-out being formed, or had only increased the possibility of one being formed in the future. In each year, a small number of projects reported that involvement had led to concrete plans for a spin-out or to an actual spin-out being created. Figure 25 illustrates that a considerable number of projects had plans to establish spin-outs in 2018, whether in the UK or overseas. The number of projects with plans to create spin-outs was comparatively low compared to the number of projects planning to exploit new products, services of processes through other means, such as entering into license agreements.

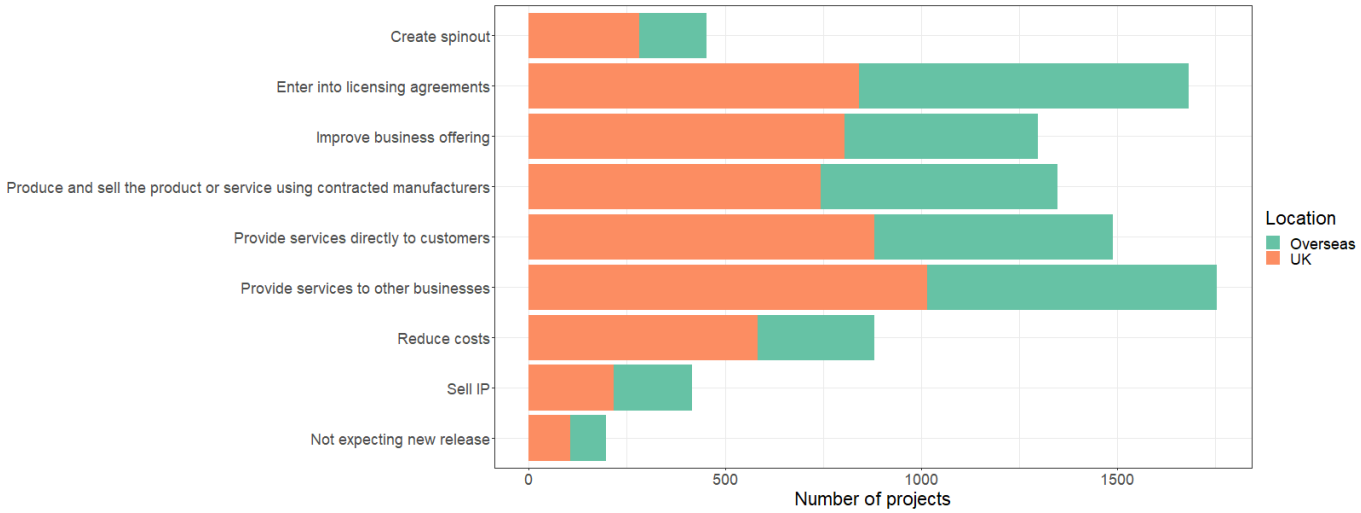
Figure 24: Number of IUK projects reporting increased the possibility of an academic spin-out being formed as a result of involvement in project (2018–2021)



Source: RAND Europe analysis of IUK data

[214] While the data presented here provide a general sense of spin-out activities outputs of IUK projects, it should be noted that data collected through PCFs may be subject to under-reporting.

Figure 25: Number of IUK projects reporting plans to establish spin-outs (and other forms of exploitation) (2018)



Source: RAND Europe analysis of IUK data

5. Connected innovation ecosystem

The fostering of multi-sectoral, multidisciplinary and multi-stakeholder collaborations and networks is a core aim of the ISCF. Such a connected innovation ecosystem is necessary for the development of innovative solutions, but also to ensure that the wider environment for adoption and improvement is in place. Through collaborative funding, as well as wider activities, ISCF funding aims to bring together coalitions of stakeholders to drive the Challenges forward. Linked to this, the Fund seeks to contribute to the international recognition of the UK as a leader within the Challenge areas.

This chapter set outs the baseline landscape regarding networks, collaboration and a connected innovation ecosystem and is divided into two parts. The first part follows the approach of previous chapters by considering the baseline landscape with respect to key aspects of a connected innovation ecosystem, including sections addressing the following areas:

- **Business-business collaboration:** Providing baseline evidence for the evaluation question: 'To what extent has the ISCF increased collaboration between businesses including between younger, smaller companies and larger, more established companies up the value chain?'
- **Business-academic collaboration:** Providing baseline evidence for the evaluation question: 'To what extent has the ISCF increased business-academic engagement on innovation activities relating to the Challenge areas?'
- **Multidisciplinary and inter-disciplinary research:** Providing baseline evidence for the evaluation question: 'To what extent has the ISCF increased multidisciplinary and interdisciplinary research and innovation (MIDRI) around the Challenge areas?'
- **International recognition:** Providing baseline evidence for the evaluation question: 'To what extent have institutions and clusters participating in the ISCF Challenges been recognised for their expertise within the UK and internationally?'

In the second part of the chapter, we present the findings of a preliminary network analysis exploring connections between different ISCF Challenges and between organisations engaging with the Challenges in different ways. The network analysis provides initial insights into the relationships between ISCF Challenges and the nature of collaboration across ISCF projects during the early stages of the Fund's implementation.

5.1. Business-business collaboration

Key message: At baseline, most participants in the ISCF across Challenges had some prior experience of business-business collaboration.

Evaluation question: To what extent has the ISCF increased collaboration between businesses including between younger, smaller companies and larger, more established companies up the value chain?

There is evidence of business-business collaboration within Challenge areas at baseline. For example, at baseline, 58 per cent of participants in the Quantum Technologies Challenge had collaborated with other businesses.[215] Similarly, for the Transforming Construction Challenge, 81 per cent of survey respondents from industry had collaborated with other construction businesses in the year prior to TCC engagement.[216] Among businesses participating in the Creative Industries Clusters Programme, 66 per cent collaborated for at least some of their research at baseline, while 47 per cent conducted the majority of their research collaboratively. Of those that collaborated, 74 per cent had collaborated with other Cluster businesses at baseline, with 51 per cent of businesses in collaboration with a technology- or data-focused business.[217] For the Transforming Foundation Industries Challenge, 62 per cent of companies had collaborated with other businesses, though only 30 per cent collaborated to develop new products, services or processes.[218] Table 11 below presents more information on business-business collaboration within Challenge areas at baseline, as derived from Challenge-level baseline reports.

Table 11: Key findings on business-business collaboration at baseline

Challenge	Key findings on business-business collaboration
Data to Early Diagnosis and Precision Medicine[219]	• 76% of respondents to a baseline survey of precision medicine firms reported collaboration with other businesses in the sector, with 48% reporting collaborations with businesses outside the sector.
Quantum Technologies[220]	• According to a baseline survey, 40% of participating businesses in the Quantum Technologies Challenge had collaborated with end-users and 58% with other businesses in quantum technologies prior to the programme.
Audience of the Future[221]	• According to a baseline survey, three out of four Audience of the Future Demonstrator projects had existing relationships within their consortia before

[215] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report.'

[216] Frontier Economics, 'Transforming Construction Challenge - Baseline Report.'

[217] Frontier Economics and BOP Consulting, 'Evaluation of the Creative Industries Clusters Programme - Phase 2 Baseline and Initial Impact Reporting - the CRPDs.'

[218] SQW, 'Transforming Foundation Industries: Industrial Strategy Challenge Fund Evaluation - Baseline Report.'

[219] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report.'

[220] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report.'

[221] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report.'

	applying, while 64% of successful applicants organisations formed new partnerships through the application process (48% for unsuccessful applicants).
Robotics for a Safer World[222]	• According to a baseline survey, 90% of successful business applicants to the Robotics for a Safer World Challenge already had at least one project with a commercial partner prior to application.
Transforming Construction[223]	• According to a baseline survey, 81% of successful business applicants to the Transforming Construction Challenge had collaborated with other construction businesses in the year prior to engagement.
Transforming Foundation Industries[224]	• 62% of foundation industry businesses responding to a baseline survey had collaborated with other businesses, but only 30% had collaborated with other organisations to develop new products, services or processes.
Transforming Food Production[225]	• According to a baseline survey, 79% of successful Transforming Food Production applicants engaged in collaborative R&D in the three years before applying to the Challenge, including collaboration with universities, public research institutes, customers or clients.
Creative Industries Clusters[226]	• A baseline survey of Creative Industries Clusters businesses found that 66% collaborated on at least some of their research, and 47% conducted the majority of their research collaboratively. Of those businesses that collaborated, 74% did so with other Cluster businesses and 51% with other data- or technology-focused businesses.

Source: RAND Europe analysis of Challenge-level baseline reports

However, business-business collaboration varied between sectors, with particular issues highlighted in some Challenge areas. For the healthcare sector, for example, collaboration with industry partners is seen as being extremely difficult. One reason for this is that NHS organisations are either at risk of being seen to give away value, or are seen as difficult to work with.[227] Similarly, there was limited business-business collaboration in the SMR space at baseline[228]. While there was some collaboration within niche pockets of manufacturing, much collaboration was focused on getting technology to the point of implementation rather than going any further.[229] Within the Digital Security by Design Challenge, meanwhile, there was a need to broaden collaboration by bringing in other companies.[230]

[222] Technopolis Group and Ipsos MORI, 'ISCF Robotics and Artificial Intelligence in Extreme Environments - Baseline and Process Evaluation Report.'

[223] Frontier Economics, 'Transforming Construction Challenge - Baseline Report.'

[224] SQW, 'Transforming Foundation Industries: Industrial Strategy Challenge Fund Evaluation - Baseline Report.'

[225] SQW, 'Transforming Food Production Evaluation - Baseline: Overview Report.'

[226] Frontier Economics and BOP Consulting, 'Evaluation of the Creative Industries Clusters Programme - Phase 2 Baseline and Initial Impact Reporting - the CRPDs.'

[227] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[228] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[229] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[230] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

5.2. Business-academic collaboration

Evaluation question: To what extent has the ISCF increased business-academic engagement on innovation activities relating to the Challenge areas?

Key message: There was variability in the extent to which business-academic collaborations existed at baseline, with low levels of collaboration in some areas.

As with business-business collaboration, there is some evidence of academic-business collaboration within Challenge areas at baseline. For the Data to Early Diagnosis Challenge, 83 per cent of respondents to a baseline survey of precision medicine firms reported collaborations with universities or other higher education institutions.[231] Similarly, 81 per cent of respondents for the Transforming Construction Challenge reported that they had collaborated with academic/research organisations in the year prior to engagement in the Challenge.[232] Of businesses participating in the Creative Industries Clusters Programme, 68 per cent reported that they had collaborated with university research departments or researchers at baseline.[233] Around a third of organisations participating in the Next Generation Services Challenge reported the involvement of an academic partner in prior R&D projects.[234]

More broadly, there was variability in the extent to which business-academic collaboration was prevalent within sectors at baseline. In the healthcare sector, business and academia had a good relationship before the ISCF. This relationship was fairly mature particularly in relation to drugs and therapeutics.[235] Similarly, for Digital Security by Design, there was already industry-academic collaboration, albeit much narrower in scope.[236] By comparison, in the data and AI sector, business-academic collaboration was not as mature as it had not been around for as long.[237] In the nuclear sector, there was also limited collaboration between businesses and academics, and there was a historic and long-standing disconnect between academic research into energy storage related topics and industrial innovation.[238] This picture is broadly reflected in our analysis of the pre-award publication of ISCF award holders (Figure 26). In many areas the total number of publications is relatively low so the proportion of publications with industry co-authorship should be interpreted with caution. In addition, it should be noted that in some Challenges, many award holders will be from industry so the analysis may be influenced significantly by the extent to which those individuals can be matched in the bibliometric database. However, we do see a considerable

[231] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report.'

[232] Frontier Economics, 'Transforming Construction Challenge - Baseline Report.'

[233] Frontier Economics and BOP Consulting, 'Evaluation of the Creative Industries Clusters Programme - Phase 2 Baseline and Initial Impact Reporting - the CRPDs.'

[234] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[235] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[236] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[237] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[238] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

number of industry co-authored publications across Challenge areas and, across the Fund as whole, a total of 5.1 per cent of identified baseline publications including an industry author.

Figure 26: Industry co-authorship of baseline publications, including publications (2014–2018) for ISCF award holders matched in Dimensions

Challenge area	Number of publications	Number of papers with at least one author from industry	Percentage of papers with at least on author from industry
All ISCF	16946	865	5.1%
Accelerating Detection of Disease	0	0	N/A
Audience of the Future	120	1	0.8%
Commercialising Quantum Wave 3	103	41	39.8%
Data To Early Diagnosis and Precision Medicine	4714	262	5.6%
Digital Security by Design	1013	47	4.6%
Driving the Electric Revolution	2	2	100.0%
Faraday Battery Challenge	73	3	4.1%
Future Flight	3	0	0.0%
Healthy Ageing	1873	55	2.9%
Industrial Decarbonisation	1690	57	3.4%
Low Cost Nuclear (Phase 1)	0	0	N/A
Manufacturing Made Smarter	29	8	27.6%
Medicines Manufacturing	185	48	25.9%
National Satellite Test Facility	0	0	N/A
Next Gen Aerospace	1	1	100.0%
Next Generation Services	323	3	0.9%
Prospering From the Energy Revolution	828	48	5.8%
Quantum Technologies Wave 2	140	62	44.3%
Robotics for a Safer World	3655	141	3.9%
Self Driving Vehicles	0	0	N/A
Smart Sustainable Plastic Packaging	1035	48	4.6%
Transforming Construction	1861	81	4.4%
Transforming Food Production	69	8	11.6%
Transforming Foundation Industries	219	10	4.6%

Source: RAND Europe analysis of Dimensions data provided by Digital Science.

5.3. Multidisciplinary and interdisciplinary research

Evaluation question: To what extent has the ISCF increased multidisciplinary and interdisciplinary (MIDRI) research around the Challenge areas?

Key message: The level of multidisciplinarity at baseline is comparable to IUK and UKRI average levels

The level of multidisciplinarity at baseline is comparable to IUK and UKRI average levels. On average, 13 per cent of identified baseline publications for ISCF award holders are linked to more than one field of research, and the average number of fields of research linked to papers in the baseline publication set is 1.16,

which is comparable to the IUK and UKRI average of 1.19. There is some variation between Challenges – for example the Manufacturing Made Smarter challenge is particularly multidisciplinary, with 28.1 per cent of its publications linked to more than one field of research, and an average number of fields of research linked to the publications of 1.38.

This picture is broadly in line with the evidence from the Challenge-level baseline reports. For example, in 2020, only 19 per cent of studies for the Future Flight Challenge reported on UKRI Gateway to Research (GTR) were interdisciplinary[239], with similar levels in the years prior, indicating that few studies in the this field were interdisciplinary at baseline.[240] The Science and Technology Facilities Council (STFC) had funded early-stage multidisciplinary research through The Global Challenge Network in Battery Science and Technology since 2013.[241] At baseline, 22 Future Flight studies that involved interdisciplinary R&D were listed on the GTR portal, with a combined total value of £14m.[242]

Figure 27: Multidisciplinarity of baseline publications (2014–2018) from award holders for whom publications could be matched in Dimensions

Challenge area	Number of publications	Number of publications linked to more than one field of research	Percentage of publications linked to more than one field of research	Average number of fields of research associated with publications in the set
All ISCF	16946	2201	13.0%	1.16
Accelerating Detection of Disease	0			
Audience of the Future	120	19	15.8%	1.22
Commercialising Quantum Wave 3	103	15	14.6%	1.24
Data To Early Diagnosis and Precision Medicine	4714	325	6.9%	1.08
Digital Security by Design	1013	80	7.9%	1.10
Driving the Electric Revolution	2			
Faraday Battery Challenge	73	9	12.3%	1.16
Future Flight	3	-	0.0%	1.00
Healthy Ageing	1873	313	16.7%	1.22
Industrial Decarbonisation	1690	327	19.3%	1.23
Low Cost Nuclear (Phase 1)	0			
Manufacturing Made Smarter	29	2	6.9%	1.07
Medicines Manufacturing	185	52	28.1%	1.38
National Satellite Test Facility	0			
Next Gen Aerospace	1	0	0.0%	1.00
Next Generation Services	323	48	14.9%	1.23
Prospering From the Energy Revolution	828	163	19.7%	1.24
Quantum Technologies Wave 2	140	22	15.7%	1.25
Robotics for a Safer World	3655	471	12.9%	1.16
Self Driving Vehicles	0			
Smart Sustainable Plastic Packaging	1035	176	17.0%	1.21
Transforming Construction	1861	303	16.3%	1.21
Transforming Food Production	69	12	17.4%	1.19
Transforming Foundation Industries	219	33	15.1%	1.20

[239] For this analysis, interdisciplinary studies were defined as studies that involve at least two different Future Flight technologies. Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report'.

[240] Frontier Economics, BMG, and Frazer-Nash Consultancy.

[241] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

[242] Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report.'

Source: RAND Europe analysis of Dimensions data provided by Digital Science.

5.4. International recognition

Key message: Academic institutions in the UK are broadly considered to have world-class expertise in a range of areas relevant to the Challenges. However, this recognition is not always reflected in industry reputation, where the picture is more mixed and the strength is reliant on a small number of key players.

Evaluation question: To what extent have institutions and clusters participating in the ISCF Challenges been recognised for their expertise within the UK and internationally?

While international recognition of the UK is varied across the Challenge areas, academic institutions have broadly had the most success in being recognised for their expertise in the UK and internationally. Academic institutions in the UK were seen to have world-class expertise in a range of areas of research – such as electrochemical energy storage and quantum and cyber research.[243]

However, this strong academic research is often not translated into industry and entrepreneurialism. While there is much international research being conducted at universities, this is only loosely geared towards innovation or industry need. The UK was and is recognised as a hub for life sciences – that is, being strong academically, as well as for its pharmaceutical industry and its SMEs.[244] Despite this high degree of scientific excellence and competence, the UK's reputation was also that it was not highly entrepreneurial in this domain.[245] Similarly, while the UK is seen as having world-leading financial and professional service sectors, this reputation does not extend to collaboration or innovation.[246] Another example may be seen in the area of agritech, where the UK had a good research base and capability but did not capitalise on it, leaving key competitors in Singapore, Israel, Ireland and the United States to lead the way.[247] This provided a key rationale for the ISCF in the area of agritech – to emphasise international opportunities and to focus on export.

There are some areas in which the UK has a reputation as a world leader. The Digital Security by Design Challenge baseline report notes that the UK ranked 1st globally out of 175 countries in the 2018 Global Cybersecurity Index. Stakeholder interviews conducted at baseline suggested that the UK currently had strong or world-leading capabilities in some security, hardware and software sub-sectors.[248] The UK legal sector – relevant to the Next Generation Services challenge – is renowned for its international legal services firms, with five of the largest 15 global law firms having UK headquarters. The sector had an estimated total premium volume of just under £178bn, making it the largest in Europe and 4th largest in the world behind

[243] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[244] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[245] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[246] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[247] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[248] RSM, 'Digital Security by Design Evaluation - Phase 2: Developing the Baseline,' April 2021.

the United States, China and Japan.[249] In the healthcare domain (relevant to the Accelerating Detection of Disease, Health Ageing, Data to Early Diagnosis and Precision Medicine and Medicines Manufacturing Challenges), the creation of Genomics England helped establish the UK as a world leader in genomics. Rare Diseases UK played a leadership role in Europe, fed into advanced therapies, and has helped to build the reputation of UK excellence in life sciences.[250]

However, there were some areas in which UK reputation had declined. There are instances in which progress has been reversed; a decade ago, the UK was seen as a world leader in technology for 'ageing in place', however this leadership has been eroded.[251] In addition, Britain's vote to leave the EU in 2016 was felt by some to have had a negative reputational impact on the UK science base.[252] In 2018, international collaboration on nuclear research was at a low ebb, which workshop participants suggested was in part due to a tendency for the UK to be viewed as a market in which to sell nuclear technologies rather than a producer of them.[253]

There are some areas in which the UK is neither leading nor lagging behind – but its reputation and recognition as able to bring research collaborators together mean it could lead with the right investment. There is international recognition that the UK is good at research collaboration and bringing together the right stakeholders to solve problems.[254] In areas such as lawtech, there is limited global collaboration – meaning the UK is not necessarily ahead or behind[255]. Similarly, there is no clear global leadership in the area of manufacturing and sustainability – despite interest from the SME engineering base and some limited academic interest – meaning the UK is not really on the radar in this area.[256]

[249] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[250] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[251] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[252] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[253] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[254] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[255] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[256] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

Preliminary ISCF network analysis

Evaluation questions:

- *To what extent has the ISCF increased collaboration between businesses including between younger, smaller companies and larger, more established companies up the value chain?*
- *To what extent has the ISCF increased business-academic engagement on innovation activities relating to the Challenge areas?*

Network analysis is a type of quantitative analysis that studies the connections between things ('nodes') and draws insights from the structure of these links. For example, network analysis can be used to study the structure of friendships in social networks, co-authorship in academic research or R&D collaboration between firms. Through visualisation of the network and statistics on the structure of connections, network analysis can help investigate how entities interact with each other.

Network analysis can provide useful metrics on issues such as:

- Which nodes are most 'influential' or 'central' in the network?
- How 'clustered' vs. 'diverse' are the connections in the network?
- Does the network divide into smaller 'communities' or 'silos'?
- Are certain nodes particularly important in bridging communities together?

Network analysis goes beyond the analysis of business impacts to look at wider networks (including academics and third sector organisations) enabled and supported by the ISCF.

As part of the baselining phase, we have undertaken a preliminary network analysis that explores the connections between different ISCF Challenges and between the organisations engaging with the Challenges in two ways: events and funded projects. This preliminary network analysis provides initial insights into the relationships between ISCF Challenges and the nature of collaboration across ISCF projects.

We anticipate that it will be beneficial to conduct a similar analysis as part of the final Impact Evaluation, once the Challenges are more developed (or, in some cases, complete) and more data is available on collaboration. In this sense, while the primary focus of this preliminary network analysis is to demonstrate a 'proof of concept' for using network analysis within later stages of the evaluation[257], the preliminary

[257] The implications of this preliminary network analysis for later network analyses, including possible extensions of the analysis are discussed in Annex C.

network analysis can also provide a form of baseline, illustrating the nature of collaboration between organisations and Challenges at the early stages of the ISCF's implementation. This said, given the current early stage of the ISCF and the limitations of the data discussed below, these findings should be viewed only as preliminary. Later analysis may seek to expand on, and develop, the work done at this phase and so may not be fully comparable with results presented here. Conclusions on the implications of this preliminary network analysis for later possible network analysis, including possible extensions, are presented in Annex C of this report.

It should also be noted that this analysis is not strictly a 'baseline' in the sense used elsewhere in this report. This is because the analysis is based on the early outputs of the ISCF, rather than data on the state of collaboration at the point that the ISCF was established. Baseline (pre-ISCF) perspectives on collaboration have been captured through the review of Challenge-level baseline reports and the workshops, and are referenced elsewhere in this report.

Approach to the network analysis

As described earlier (see Section 2.2.4), for this preliminary network analysis, we have analysed two sources of data on the connections between ISCF organisations and Challenges: (i) KTN data on ISCF event attendance and (ii) Delphi data on project collaborations through ISCF grants. In both cases, the data have been analysed in two ways: as a network of organisations and as a network of Challenges. The approach is described further in Table 12 below.

Table 12: Approach to network analysis of KTN and Delphi data

	KTN data	Delphi data
Network of organisations	Nodes in the network are all the organisations that have attended ISCF events. Two organisations are connected if their members attended the same event. The weight of the connection is the number of event attendances the two organisations have in common.	Two organisations are connected if they are collaborators on at least one mutual project. The weight assigned to this connection reflects the total grant that these organisations were awarded across all mutual projects.[258]
Network of Challenges	Nodes in the network are the ISCF Challenges themselves. Two Challenges are connected if a single organisation attended events for both Challenges. The weight of the connection between these Challenges is the number of attendees sent by organisations that attended events for both Challenges.	Two challenges are connected if at least one organisation is involved with projects associated with both Challenges. The weight assigned to this connection reflects the total grant received for these projects by the organisations that were involved in projects associated with both Challenges.[259]

[258] Specifically, for any two organisations that are both involved in a mutual project and receive grants of £A and £B respectively for this project, we take the minimum of A and B as the weight of the connection between these organisations. If these organisations are involved in multiple mutual projects, we take the sum of the minimum grants received by the two organisations across all mutual projects. We note below that weighting by the value of funding does not necessarily reflect the 'value' of the collaboration; possible explorations of unweighted versions of the analysis could be explored as a sensitivity as part of the final evaluation report.

[259] Specifically, if an organisation receives grants worth £A for projects associated with one Challenge and grants worth £B for projects associated with another Challenge, we take the minimum of A and B as the weight of the connection between these Challenges. If multiple organisations are involved in projects associated with both Challenges, we take the sum of the minimum grant amounts between the two Challenges for all organisations.

In the sections that follow, we present findings from the analysis of KTN data and Delphi data in turn. Both types of data have drawbacks as well as advantages. Mutual event attendance does not necessarily imply a collaborative link between organisations (though it signals the potential for such a link). Additionally, the results may depend somewhat on the number of events held that we can associate with each Challenge in the data: Challenges holding more events are, by definition, more likely to be 'connected' with other Challenges, and organisations attending those events are more likely, through sheer numbers, to be connected with other organisations.

On the other hand, data on formal collaboration through project grants does not necessarily reflect more informal patterns of collaboration between organisations and Challenges. Additionally, the results may depend to some extent on the number of project grants that have so far been awarded for each Challenge to date. It is also important to note that our approach to weighting connections in the Delphi data assumes that a participant's collaboration on a project reflects the level of the grant received. The actual determinants of the level of collaboration between the members of a project will, in reality, be more complex, but therefore not possible to observe or quantify in the same way.

Due to the different perspectives, strengths and shortcomings of the data sources, it is informative to compare and contrast analysis of both.[260]

Treatment of universities and academic institutions

A key indicator is 'network centrality'. This captures how well-connected and integrated in a network a particular node is. For both the KTN and Delphi data, it was found that universities and academic institutions have the highest network centrality, based on several measures. The finding that universities have a much higher network centrality likely reflects the fact that these institutions generally have multiple departments covering a wide range of subject areas and, therefore, have a wide range of engagement across ISCF Challenges.

While this is an interesting (if not unexpected) result to observe in the data, it also highlights a potential issue with respect to including these academic institutions in the analysis. Given that university departments are relatively distinct organisational units in many cases, inclusion of universities as single organisations may generate links between Challenges that are not representative of actual collaboration or engagement activity. For this reason, the results presented below exclude universities and academic institutions.[261] This is a

[260] Comparing these gives an initial assessment of whether the networks look different when we consider ISCF-enabled events and funded projects. In practice, as we discuss below, it may be possible to combine these into a single dataset for future evaluation. However, we also note both that this introduces conceptual difficulties about how to 'weight' funding and event attendance in terms of the size of a connection between organisations and Challenges; and that preliminary assessment of the two datasets suggests that there is (perhaps surprisingly) relatively little overlap between them (see Annex D relating to econometric analysis).

[261] For the KTN data, any organisations with the type 'University, Research Institute or RTO' are excluded. For the Delphi data, any organisations flagged as 'Academic' are excluded.

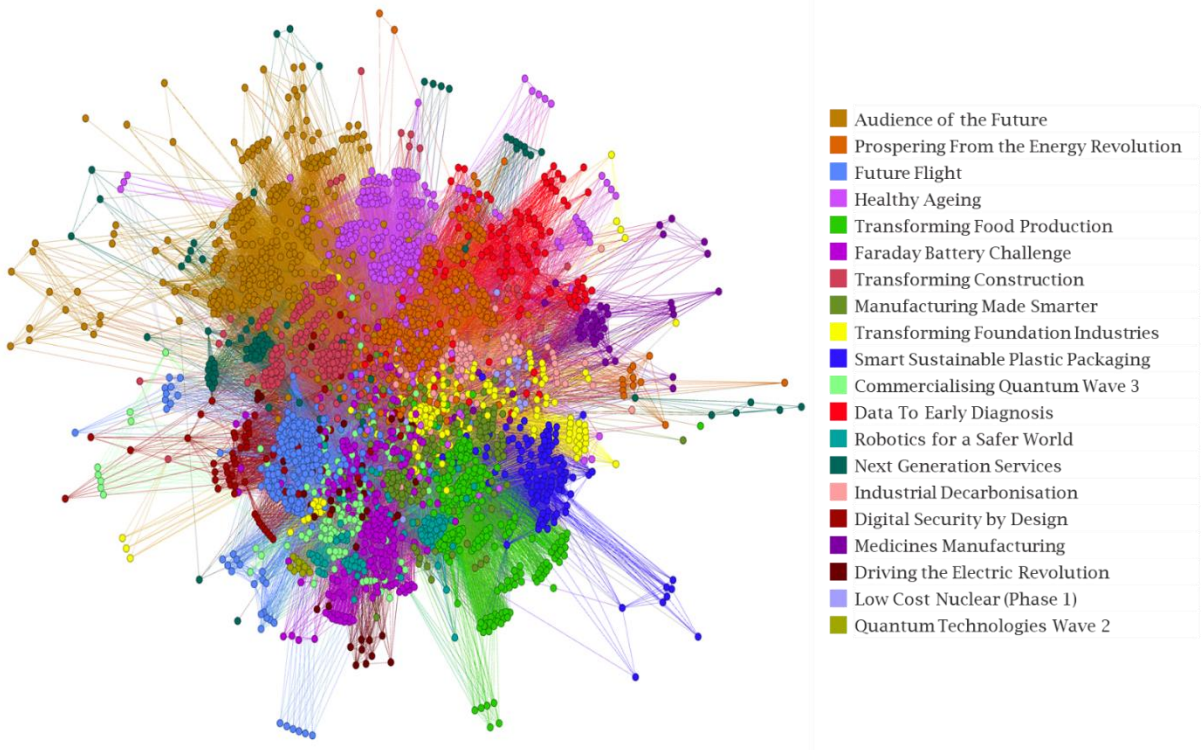
limitation of the datasets, where details of the individual academic(s) or departments attending events were not collected or available.[262]

KTN data

Network of organisations

Key message: Data on event attendance suggests a rich pattern of connectivity and engagement across the ISCF Challenges, with no obvious silos within the network.

Figure 28: Network of organisations (KTN data)[263]



Source: Frontier Economics analysis of KTN ISCF event data

Figure 28 above shows a visualisation of the network of organisations for the KTN event data. Each dot (node) represents an organisation and is coloured corresponding to the Challenge that it engaged with most (in terms of event attendance). The nodes are arranged in the visualisation such that more strongly connected nodes are closer together. Nodes near the centre of the image typically have the most connections.[264]

[262] In principle, there may be similar concerns for businesses, particularly large conglomerate firms. We have not tested the sensitivity of our results to this at this stage, though in general the numbers of such businesses are relatively low.

[263] Next Generation Aerospace and Self Driving Vehicles are not shown as no events could be reliably identified for these Challenges.

[264] Formally, we use the Yifan Hu Multilevel layout. See Yifan Hu, 'Efficient and High Quality Force-Directed Graph Drawing,' *The Mathematical Journal* 10, no. 1 (2005): 37–71.

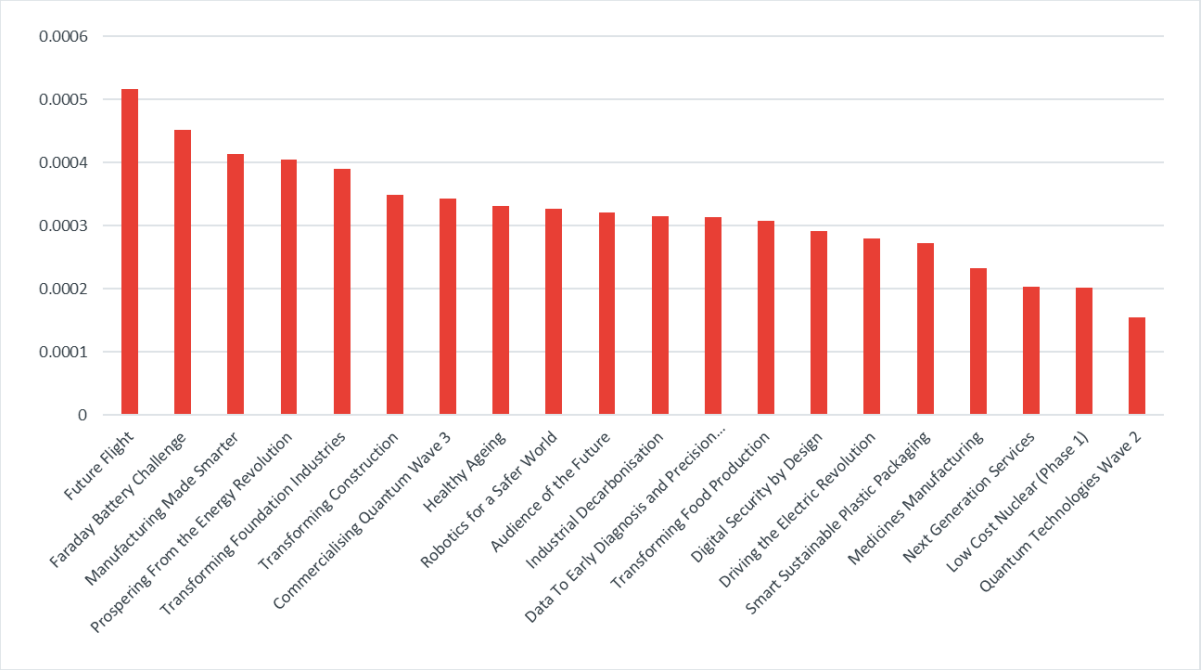
This visualisation shows a rich pattern of connectivity and engagement across the ISCF Challenges. Visually, clusters of organisations associated with a single main Challenge (i.e. clusters of a single colour) can be identified. The arrangement of these clusters gives some indication of overlapping participation by organisations between Challenges.

For example, near the centre of the network we see several organisations associated with Transforming Construction, Prospering from the Energy Revolution, Industrial Decarbonisation and Faraday Battery. In the bottom right of the image, we see clusters related to Transforming Food Production, Smart Sustainable Plastic Packaging, Robotics for a Safer World and Manufacturing Made Smarter.

There are no obvious silos in the network. That is to say, there do not appear to be any large clusters of organisations that are closely connected with each other but poorly integrated into the wider network.

On average, organisations that engaged the most with Future Flight, Faraday Battery and Manufacturing Made Smarter have the highest 'centrality' in the network (as measured by 'Page Rank').[265] This is shown in Figure 29 below. This suggests that these organisations are generally the most well-connected and integrated into the network.

Figure 29: Average page rank of organisations by Challenge (KTN data)



Source: Frontier Economics analysis of KTN ISCF event data
Note: Page Rank is a measure of network centrality that accounts for the number and strength of a node's connections but also the number and strength of the nodes it is connect to in turn [266].

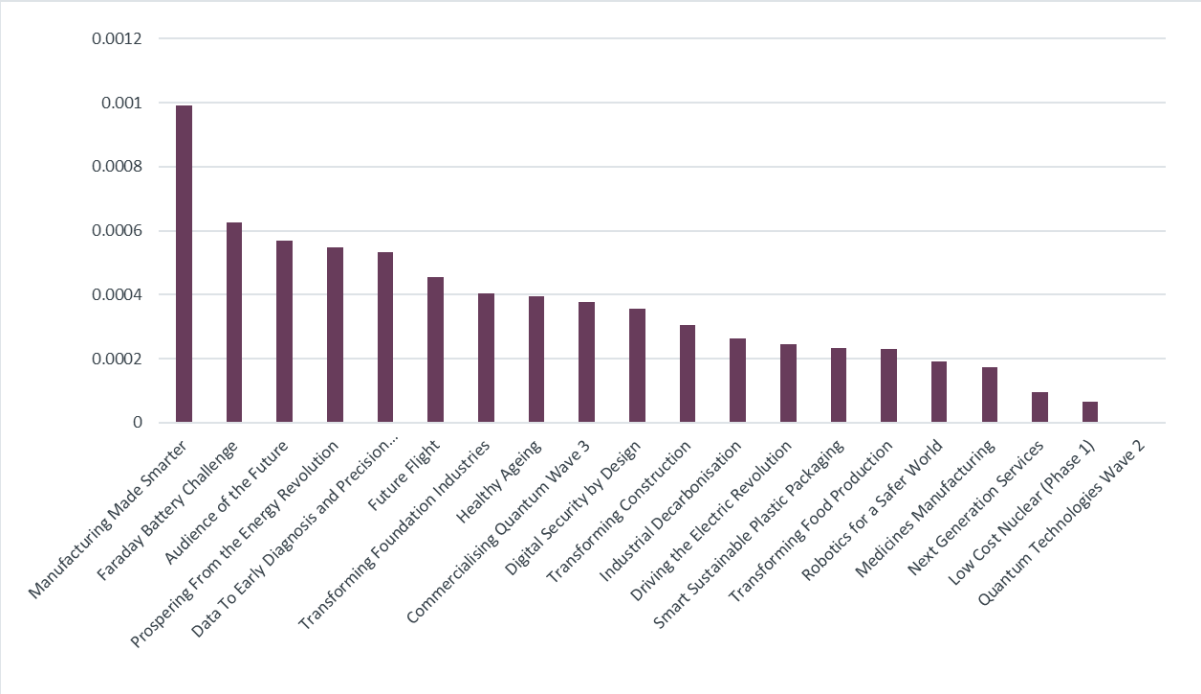
[265] Page Rank is a measure of network centrality that accounts for the number and strength of a node's connections but also the number and strength of the nodes it is connect to in turn Sergey Brin and Lawrence Page, 'The Anatomy of a Large-Scale Hypertextual Web Search Engine,' *Proceedings of the Seventh International World Wide Web Conference* 30, no. 1 (April 1, 1998): 107–17, https://doi.org/10.1016/S0169-7552(98)00110-X.

[266] Brin and Page.

However, it is possible that a high Page Rank is driven by strong connections with other organisations that mostly attended events of the same Challenge, rather than reflecting a high level of connectivity across Challenges. It is therefore important to look at a range of metrics in the round.

As shown in Figure 30 below, organisations associated with the Manufacturing Made Smarter Challenge also have a substantially higher 'betweenness'[267], on average. This suggests that, in addition to having a high Page Rank, these organisations act as a kind of 'bridge' connecting otherwise more distantly related organisations. This may reflect the relevance of manufacturing to a number of other Challenges. Organisations associated with the Faraday Battery Challenge also have a high average betweeness, in addition to their high Page Rank.

Figure 30: Average 'betweenness' of organisations by Challenge (KTN data)



Source: Frontier Economics analysis of KTN ISCF event data
Note: Betweenness is a measure of centrality that reflects the number of shortest paths between pairs of nodes that a given node lies on [268].

Conversely, while organisations that engaged most with the Future Flight Challenge have a high Page Rank, they do not have as high a Betweeness. This may suggest that the high Page Rank of these organisations may be driven by strong mutual event attendance within this Challenge, rather than connectivity across Challenges.

We can further validate these findings by looking at the data as a network of Challenges.

[267] Betweenness is a measure of centrality that reflects the number of shortest paths between pairs of nodes that a given node lies on Ulrik Brandes, 'A Faster Algorithm for Betweenness Centrality,' *The Journal of Mathematical Sociology* 25, no. 2 (June 1, 2001): 163–77, https://doi.org/10.1080/0022250X.2001.9990249..

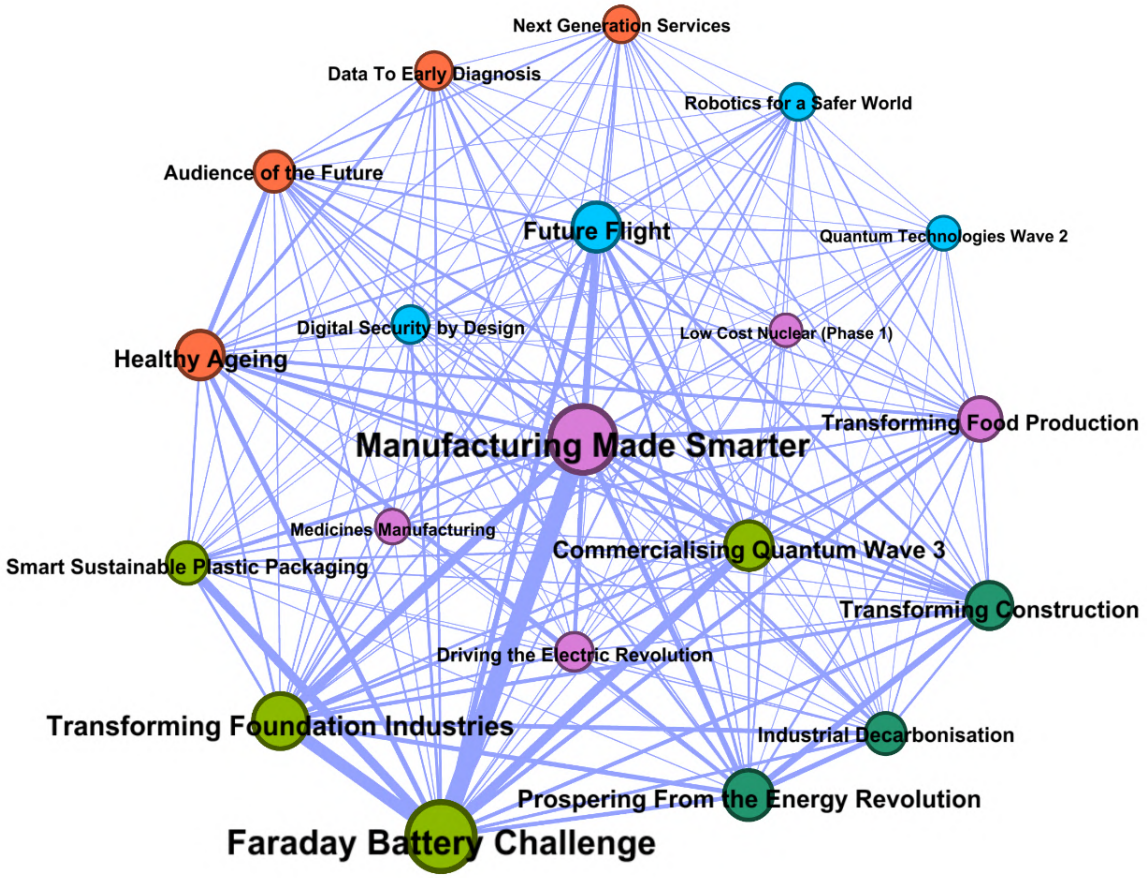
[268] Brandes.

Network of Challenges

Key message: Based on event attendance data, ISCF Challenges can be grouped into five 'communities'. While these communities are broadly intuitive and reflect alignment between certain Challenges areas, others are more surprising and link together seemingly unrelated Challenges.

As described above, it is also possible to analyse the data as a network of Challenges. Figure 31 below visualises the data from this perspective. Each node represents a Challenge and its size reflects its network centrality (Page Rank). The thickness of the links between Challenges reflects their 'weight'.

Figure 31: Network of Challenges (KTN data)[269]



Source: Frontier Economics analysis of KTN ISCF event data
Note: The 'weight' of the connection between Challenges is the number of attendees that attended events for both Challenges.

As with the network of organisations, we see that the Faraday Battery and Manufacturing Made Smarter Challenges have the highest network centrality. It is worth noting that this is not simply driven by the number of events held by each Challenge to date; a number of Challenges have held more events than the

[269] Nodes are arranged according to a Fruchterman-Reingold layout Thomas M. J. Fruchterman and Edward M. Reingold, 'Graph Drawing by Force-Directed Placement,' *Software: Practice and Experience* 21, no. 11 (November 1, 1991): 1129–64, https://doi.org/10.1002/spe.4380211102.

Faraday Battery and Manufacturing Made Smarter Challenges, but are less well-connected with the wider ISCF network on this measure.[270]

To better understand the relationships between the Challenges and overall structure of the network, we deployed a 'community detection algorithm' to group together those Challenges more closely connected to one another. This grouping is based only on connections in the network data, and uses no prior knowledge about the nature of the Challenges. The grouping is shown in the visualisation above, with each Challenge coloured according to its identified community.[271]

The Challenges are grouped into five communities. Generally, these groupings are quite intuitive given the subject areas of the Challenges. For example, three Challenges with an explicit focus on decarbonisation (Transforming Construction, Prospering from the Energy Revolution and Industrial Decarbonisation) are grouped, as are a number of Challenges with a clear focus on the manufacturing sectors. **Some connections are perhaps more surprising**, such as the link between Healthy Ageing and Audience of the Future, though we note the involvement of Nesta in both Challenges.

Delphi data

Network of organisations

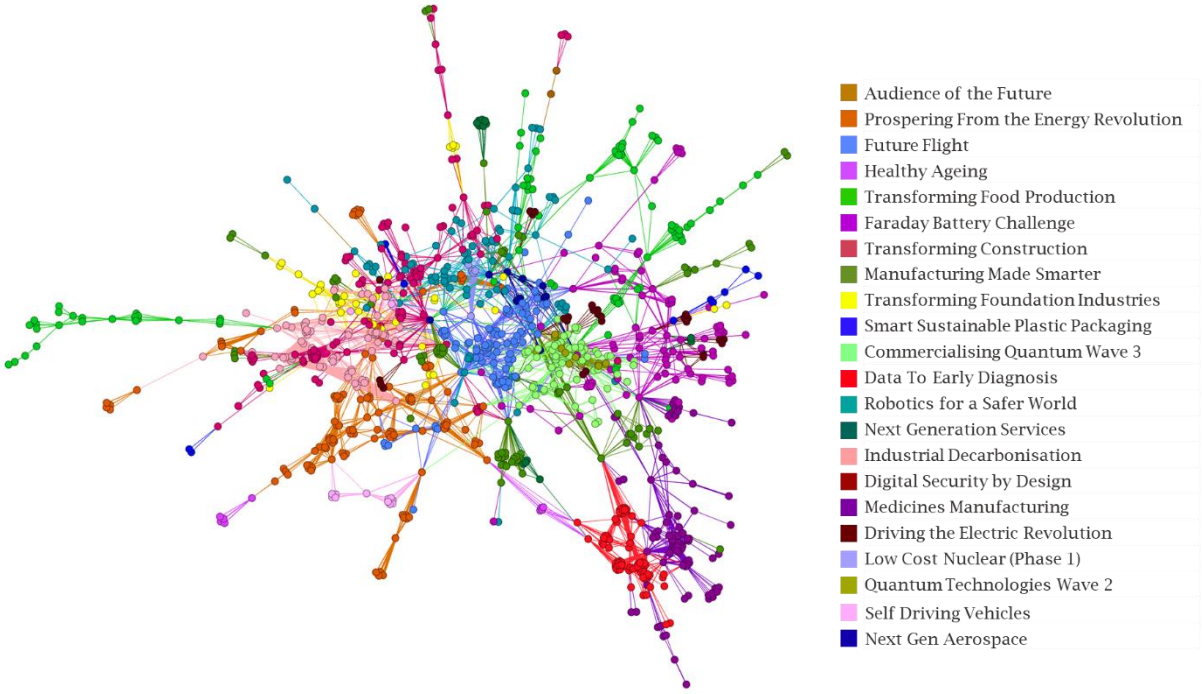
Key message: Compared to event attendance data, data on project collaboration suggests a more sparsely connected network comprised of fewer organisations, and with some silos. Large organisations are not significantly better connected than smaller organisations, but may play an important bridging role within the network.

We can compare network analysis of the KTN data with the Delphi data. Figure 32 below visualises the network of organisations based on the Delphi project data. This is equivalent to Figure 28 above and has been produced in the same way.

[270] Table 14 in Annex D shows the number of KTN events identified for each Challenge.

[271] The community detection algorithm used is based upon Vincent D Blondel et al., 'Fast Unfolding of Communities in Large Networks,' *Journal of Statistical Mechanics: Theory and Experiment* 2008, no. 10 (October 9, 2008): P10008, https://doi.org/10.1088/1742-5468/2008/10/p10008..

Figure 32: Network of organisations (Delphi data)[272]



Source: Frontier Economics analysis of Delphi data

Compared with the network of organisations based on event attendance, this network is more sparsely connected with fewer organisations. This is to be expected given that connections in the Delphi data represent formal collaboration on a funded project, a more significant and less common form of connection between organisations than mutual event attendance.[273]

As before, clusters of organisations that primarily engage with a particular Challenge can be visually identified and the proximity of these clusters provides some indication as to the connectivity between these clusters. One group of organisations that visually appears to represent somewhat of a silo are those working on the Data to Early Diagnosis and Medicines Manufacturing Challenges (pictured bottom-right). These organisations have only a small number of connections with the wider network, mostly via Manufacturing Made Smarter and Faraday Battery.

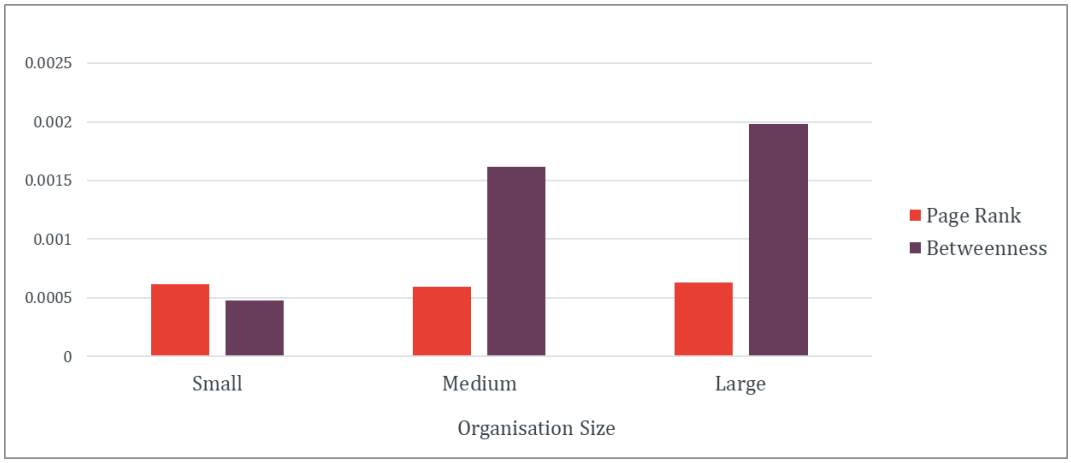
We explored key measures of network centrality by organisation size (Figure 33Figure 33 below), finding that large organisations are not significantly better connected when measured by Page Rank, but have a higher average betweenness score. This higher betweenness score of larger organisations could reflect larger organisations being more likely to be involved in multiple ISCF Challenges and therefore playing more of

[272] Only the largest connected component is shown. That is to say, there are a number of small groups of organisations (mostly pairs) that are only connected to each other and are not connected to the wider network. These organisations are not pictured here.

[273] The KTN dataset contained more than 4,400 unique organisations whereas the Delphi dataset contained around 2,170.

a role in bridging the network together.[274] However, it is less clear why large firms should have only a slightly higher Page Rank than small firms. It may be because large firms form most of their links with small firms and small firms form most of their links with large firms.[275] It will be interesting to see if this result holds in later analysis.

Figure 33: Average network centrality by organisation size (Delphi data)



Source: Frontier Economics analysis of Delphi data

Network of Challenges

Key message: The network of Challenges based on project collaboration data suggests different communities to those based on event attendance data, reflecting the different nature of project-based collaboration.

Figure 34 below visualises the Delphi data as a network of Challenges. This is equivalent to Figure 31 above and is produced in the same way. As in the KTN data, we find that the Faraday Battery Challenge is relatively well-connected. We find that Commercialising Quantum Wave 3 has the highest Page Rank and Robotics for a Safer World has the highest betweenness.

Visually, we see a strong link between Transforming Construction and Next Generation Aerospace. This is driven by organisations such as the Manufacturing Technology Centre (MTC), Autodesk and the National Composites Centre. To a lesser extent, there also appears to be a strong link between Medicines Manufacturing and Faraday Battery. This appears to be driven mostly by the Centre for Process Innovation (CPI) engaging in a number of projects for both Challenges.

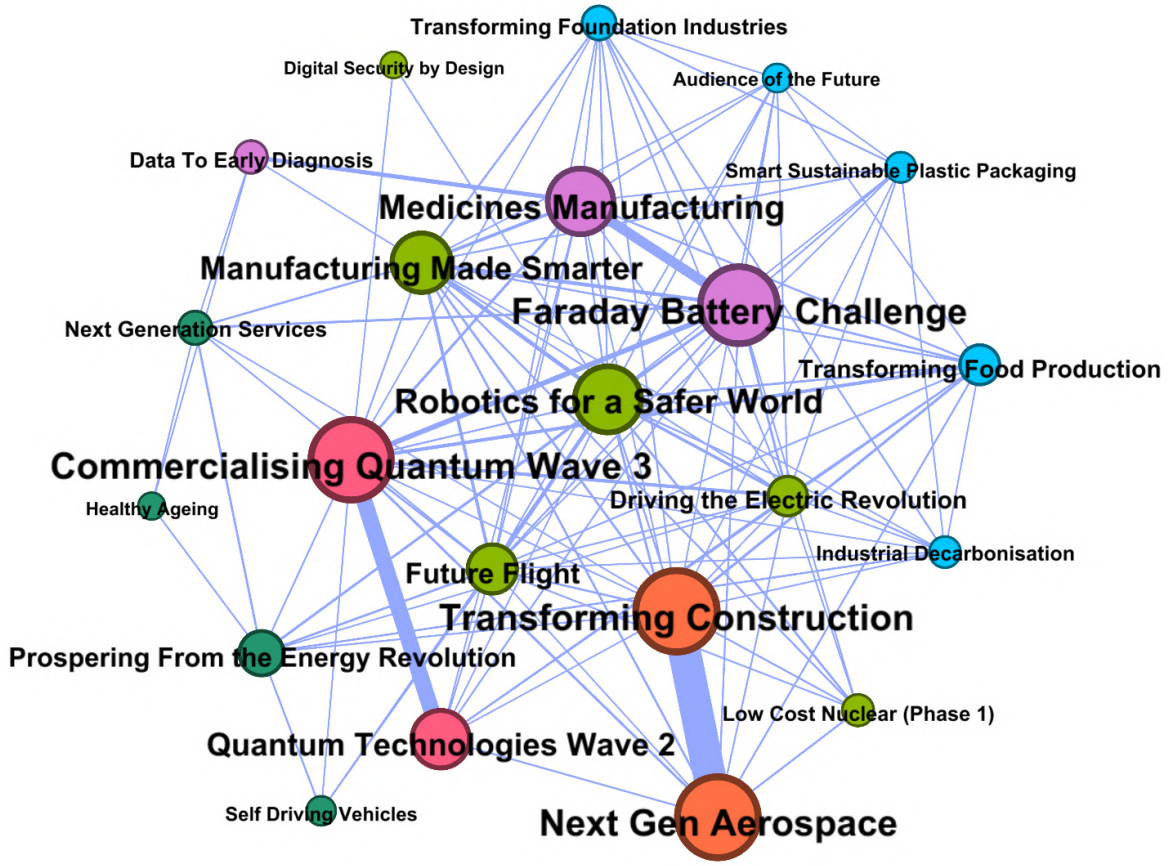
Looking at the network based on commonly funded organisations through projects presents a different picture from that based on common event attendees, with different communities identified through

[274] Large organisations are involved in 1.2 Challenges on average, compared to 1.07 Challenges for small organisations. Large organisations also have a higher number of collaborators on average than small organisations (9.0 and 5.8, respectively).

[275] Around 50% of the links of large firms are with small firms and 30% are with other large firms. Conversely, around 51% of small firms links are with large firms and only 32% are with other small firms. Note that the sample contains 822 small firms, 203 medium firms, and 501 large firms.

the detection algorithm. This likely reflects the very different nature of the common interactions between lighter touch events and more intensive collaborative projects.

Figure 34: Network of Challenges (Delphi data)[276]



Source: Frontier Economics analysis of Delphi data
Note: The 'weight' of the connection between Challenges reflects the total grant received for projects by organisations that were involved in projects associated with both Challenges.

[276] Nodes are arranged according to a Fruchterman-Reingold layout Fruchterman and Reingold, 'Graph Drawing by Force-Directed Placement'

6. Economic impact

Through the creation of knowledge and innovation pathways, enhanced capacity and investment, and the establishment of a connected innovation ecosystem, the ISCF aims to deliver long-term economic impacts for the UK. This includes the growth of UK businesses and expansion into new markets and sectors, increased GVA and productivity, and increased spread of economic benefits across UK regions. This chapter provides evidence regarding the economic landscape within the Challenge areas and associated business at baseline. The chapter's sections consider:

- **State of UK businesses:** Providing baseline evidence for the evaluation question 'To what extent have the ISCF Challenges supported the growth of UK businesses and created new markets or enabled increase of the UK's share in global market in their respective sector?'
- **GVA and productivity**[277]**:** Providing baseline evidence for two evaluation questions: 'What has been the increase in gross value add (including the creation of new products and services in relevant sectors and/or the creation of new markets)?' and 'What has been the productivity change (capital, labour or combined)?'
- **Regional spread:** Providing baseline evidence for the evaluation questions: 'While the ISCF is place-agnostic, to what extent have the economic impacts of the ISCF been widely distributed across the UK?'

[277] Note that our analysis of GVA and productivity at baseline is based on methodologies used in the Challenge-level baseline reports and hence definitions may vary depending on the methodologies used in those analysis. However, in the econometric analysis to be conducted in phase 4 of the evaluation we will assess GVA and productivity across businesses using the data provided in the business structure database, including assessment of the baseline state for both businesses involved in the ISCF and a comparator set of businesses. Therefore, the analysis will be directly baselined using comparable measures; the analysis provided here just sets out some initial context and will not be used in later direct numerical comparisons of productivity and GVA.

6.1. State of UK businesses

Evaluation: To what extent have the ISCF Challenges supported the growth of UK businesses and created new markets or enabled increase of the UK's share in global market in their respective sector?

Key message: The ISCF supports a wide variety of UK businesses working in sectors with very different characteristics. Some businesses were working in large, well-developed sectors already on the rise at baseline, while others were smaller and less well-established.

Turnover figures varied considerably by sector, with some businesses deriving no turnover from Challenge relevant activities pre-baseline. For example, in 2016, the legal services sector alone generated a total revenue of £35.4bn,[278] while companies in the aviation and aerospace sectors had a collective turnover of nearly £85bn at baseline.[279] Smaller, emerging sectors, such as the creative immersive sector associated with Audience of the Future had much lower turnover; indeed, at baseline, two out of five ISCF-funded business derived no turnover from immersive content or technologies.[280]

Trends in turnover were also mixed at baseline. Turnover in Challenge sectors was largely flatlining or declining in some sectors, such as UK battery manufacturing, which fell in real terms from £405m to £349m between 2010 and 2017. Other sectors, such as the foundation industries, saw increases in turnover, but at nearly half the rate of the wider non-financial economy over 2014–19 (1.1 per cent compared to 1.9 per cent average annual growth).[281] Some sectors, such as the UK medicine technology (medtech) sector did grow (by 37 per cent over 2015–2018, representing double the growth rate in Germany, albeit from a lower base).[282] Other examples of industries with growing turnover include the accounting sector within NGS (which, as a whole, grew by ~3.7 per cent each year between 2014 and 2019)[283], and digital health within the broader medicines manufacturing sector.[284] Figure 35 provides more detail on turnover figures and trends within specific Challenge areas, as reported by Challenge-level baseline reports.

[278] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[279] Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report.'

[280] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report.'

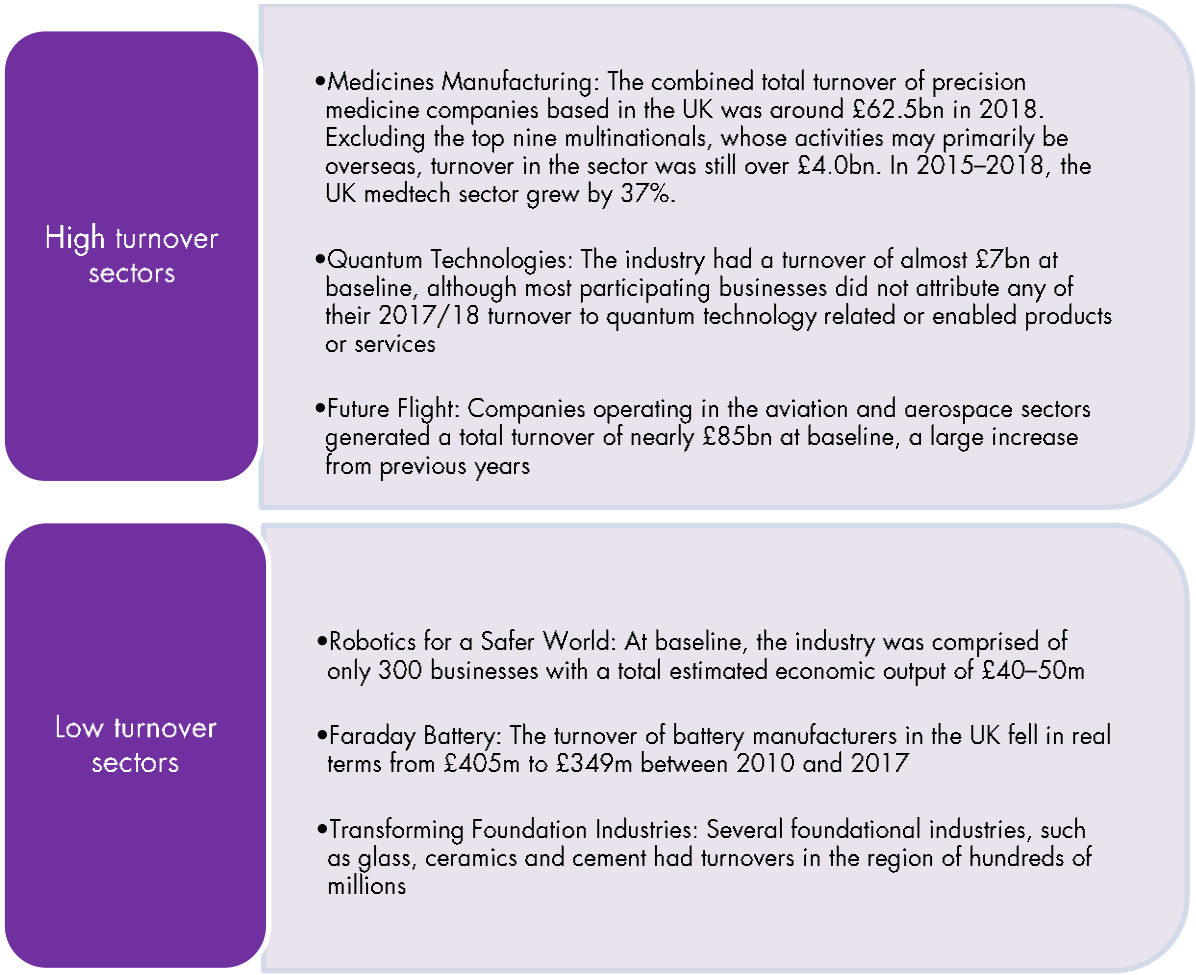
[281] SQW, 'Transforming Foundation Industries: Industrial Strategy Challenge Fund Evaluation - Baseline Report.'

[282] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report.'

[283] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[284] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report.'

Figure 35: Sector-level turnover figures and trends at baseline



Source: RAND Europe analysis of Challenge-level baseline reports

Similar to turnover figures, exports by UK businesses varied widely at baseline. Perhaps unsurprisingly, reflecting their high turnovers noted above, the accounting industry and future flight sectors had high exports of £2.5bn and £14.5bn respectively.[285] By contrast, the robotics and AI in extreme environments sector had exports of only £5m at baseline, reflecting its status as an emerging area.[286]

Finally, some Challenge-relevant sectors were niche, with only a select few active organisations, while others were already large and covered thousands of organisations. Among all Challenge-relevant sectors, the core UK battery manufacturing sector was particularly small, comprised of only 53 firms in 2017.[287] Similarly, at baseline the robotics and AI in extreme environments sector was made up of around only 300

[285] Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report'; Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[286] Technopolis Group and Ipsos MORI, 'ISCF Robotics and Artificial Intelligence in Extreme Environments - Baseline and Process Evaluation Report.'

[287] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

businesses.[288] Other sectors were considerably larger, such as the creative immersive and the aviation sectors, involving 1,406 and 5,503 companies respectively at baseline.[289]

6.2. GVA and productivity

Evaluation questions:

- *What has been the increase in gross value added (including the creation of new products and services in relevant sectors and/or the creation of new markets)?*
- *What has been the productivity change (capital, labour or combined)?*

Key message: With some exceptions, the GVA and productivity of Challenge-relevant sectors were largely increasing prior to baseline broadly in line with wider trends for UK GVA growth.

Absolute levels of GVA and productivity were significantly different across Challenge-relevant sectors at baseline. Certain Challenges-relevant sectors, such as pharmaceutical manufacturing and services (e.g. legal, accounting and insurance) were large and well-developed, recording GVA of several to tens of billions of pounds.[290] Others, such as the battery manufacturing sector, were considerably smaller, recording GVA values of £149m at baseline.[291] Businesses working in industrial decarbonisation were even smaller, having a GVA of around £1.25m at baseline.[292]

In several sectors, such as pharmaceutical manufacturing, agriculture, services, battery technology and advanced materials, productivity and GVA were high or increasing prior to baseline. Legal services, for example, experienced a constant increase between 2013 and 2018, growing around 20 per cent in GVA terms over the period.[293] The battery manufacturing sector output (GVA) also increased from £133m to £149m in real terms between 2010 and 2017.[294] However, the battery sector's absolute level of GVA was significantly lower than other sectors experiencing GVA growth. Productivity, defined as GVA per worker, increased in the agriculture sector pre-baseline, but this was not sufficient to close the productivity gap with the UK average, and a substantial productivity deficit was evident at baseline.[295] For comparison, the UK

[288] Technopolis Group and Ipsos MORI, 'ISCF Robotics and Artificial Intelligence in Extreme Environments - Baseline and Process Evaluation Report.'

[289] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report'; Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report.'

[290] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report'; Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[291] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

[292] Ipsos MORI, 'Industrial Decarbonisation Challenge - Baseline Report.'

[293] Technopolis Group, 'ISCF Next Generation Services Evaluation - [D2] Baseline Report - Draft.'

[294] Ipsos MORI et al., 'Industrial Strategy Challenge Fund: Faraday Battery Challenge - Baseline Report.'

[295] SQW, 'Transforming Food Production Evaluation - Baseline: Overview Report.'

GVA as a whole grew by 12 per cent on average between 2010 and 2016.[296] Within advanced materials sector, GVA per employee was £116,896 in 2016, compared to £49,532 for all UK and £65,657 for UK manufacturing.[297]

Within the aviation, manufacturing and construction sectors, the overall picture was of flat or declining GVA and lower levels of productivity. The GVA of the aviation sector decreased from £32bn to £30bn between 2017 and 2018, and productivity in the construction sector in 2018 was no higher than it had been a decade earlier.[298] Productivity in the foundation industries was actually in decline pre-baseline, dropping at an average annual rate of 0.4 per cent, broadly in line with manufacturing (-0.6 per cent per annum).[299] Figure 36 below shows trends in GVA and productivity across different Challenges.[300]

[296] House of Commons Library, 'Regional and Local Economic Growth Statistics,' 2018, https://commonslibrary.parliament.uk/research-briefings/sn05795/.

[297] Adroit Economics Ltd., 'Materials for Mobility.'

[298] Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report'; Frontier Economics, 'Transforming Construction Challenge - Baseline Report.'

[299] SQW, 'Transforming Foundation Industries: Industrial Strategy Challenge Fund Evaluation - Baseline Report.'

[300] Ipsos MORI, Technopolis Group, and Barrett, 'Industrial Strategy Challenge Fund: Medicines Manufacturing - Baseline and Process Evaluation Report.'

Figure 36: GVA and productivity trends at baseline by Challenge

Increasing GVA and/or productivity

- Medicines Manufacturing: GVA of pharmaceutical manufacturing in the UK saw a slump after 2010, but has since recovered. In 2017, the sector recorded GVA of £8.6bn and total turnover of £18.2bn, in real terms. GVA per worker in UK pharmaceutical manufacturing in 2014 was £154,000, 40% higher than in Germany and Italy, and almost twice as high as in France.
- Next Generation Services: The UK legal sector's GVA was valued at £59.9bn in 2018. The sector experienced a constant increase between 2013 and 2018, growing around 20% in GVA terms over the period. In 2016, the UK insurance industry was responsible for £29.5bn worth of UK GVA, and it has been increasing by an average of ~£1b a year since 2002, including auxiliary services.
- Faraday Battery: Battery manufacturing sector output (GVA) increased from £133m to £149m in real terms between 2010 and 2017. UK battery sector productivity, measured using GVA per worker, increased in real terms from £66,300 to £74,500 between 2010 and 2017 but mostly remained stable across the period. The sector was mostly more productive than the manufacturing sector and the UK economy overall.
- Transforming Food Production: From 2010, the UK's agricultural sector saw an improvement in productivity performance. Productivity growth outpaced the UK average, in part due to falling levels of employment in the sector. However, this was not sufficient to close the productivity gap with the UK average, and a substantial productivity deficit was evident when the Challenge was launched in 2017.
- Next Generation Aero Materials: Within the advanced materials sector, GVA per employee was £116,896 in 2016, compared to £49,532 for all UK and £65,657 for UK manufacturing.

Stagnating or declining GVA and/or productivity

- Industrial Decarbonisation: From 2010 to 2018, the average GVA of IDC firms was broadly flat, fluctuating between £0.93m in 2010 and £1.25m in 2014, with no discernible trend.
- Future Flight: GVA by companies operating in the aviation and aerospace sectors was more than £30bn in 2018. This was slightly down from a peak of £32bn in 2017. Average productivity was approximately £100,000 across the aviation and aerospace sector in 2018, but there is large variation between sub-sectors.
- Transforming Foundation Industries: Labour productivity growth was flat over 2014-19 for the wider non-financial economy, while in the foundation industries it declined at an average annual rate of 0.4%, broadly in line with manufacturing (-0.6% per annum). Within the foundation industries, labour productivity (as measured by GVA per worker) increased in chemicals (+1.7% average annual growth), glass (+4.1%), ceramics (+4%) and cement (+24.4%, driven by a sharp increase over 2014-15), while it declined in paper and pulp (4.6%) and metals (-10%). Four of the UK's six foundation industries sectors (paper and pulp, glass, metals and cement) were the least productive among comparator countries considered.
- Transforming Construction: Productivity in the construction sector in 2018 was no higher than a decade earlier.

Source: RAND Europe analysis of Challenge-level baseline reports

6.3. Regional spread

Evaluation question: While the ISCF is place-agnostic, to what extent have the economic impacts of the ISCF been widely distributed across the UK?

Key message: From the limited evidence available on Challenge-relevant UK businesses, most businesses were concentrated in London and the South East, in line with broader national trends.

While there is limited evidence on regional spread of Challenge-supported UK businesses, with few Challenge-level baseline reports addressing this directly, the evidence available points to concentrations in London and the South East. For example, the biggest proportion of precision medicine companies are based in London (22.7 per cent) followed by the South East (20.7 per cent) and East of England (14.3 per cent) [301]. Similarly, London and the South East dominate the quantum technology sector with 23 per cent and 21 per cent of relevant businesses based there respectively [302]. The regional skew is even more pronounced in the creative immersive sector, where the London workforce accounts for almost 46 per cent of the total workforce [303]. This regional skew in Challenge-level businesses was in line with the broader distribution of all UK businesses at baseline, with London and the South East accounting for 35 per cent of the UK business population in 2018 [304], and with trends in the geographical distribution of R&D investment in the UK (as discussed in Section 4.5). Reflecting this national picture, the South East, East of England, and London were also leaders in R&D employment, with 50,000, 42,000, and 31,000 full time equivalents (FTEs) respectively. This is highlighted below in Figure 37. It should be noted that this also reflects, in part, larger trends in distribution of the UK population across regions, with 27 per cent of the UK population based in London and the South East of England in mid 2018.[305]

[301] SQW, 'Data to Early Diagnosis and Precision Medicine: ISCF Challenge Evaluation - Baseline Evaluation Report.'

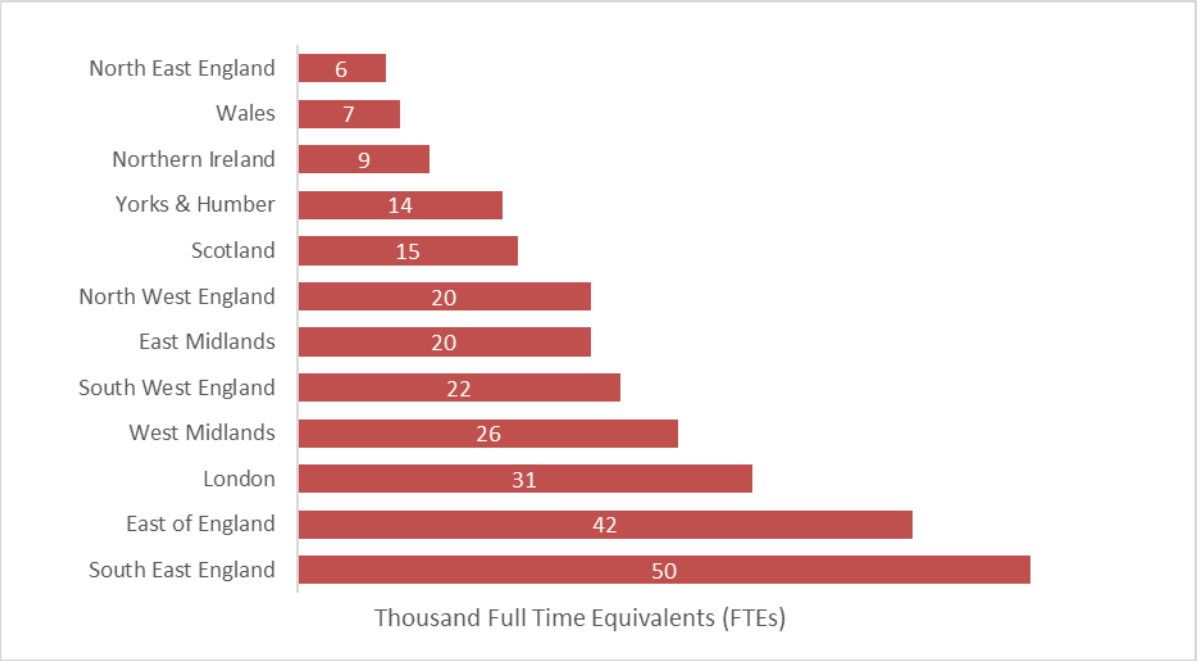
[302] Technopolis Group, 'ISCF Quantum Technology Programme Evaluation - [D3] Phase 2.2: Baseline Report.'

[303] Technopolis Group and BOP Consulting, 'Evaluation of the ISCF Audience of the Future - Baseline and Interim Process Evaluation Report.'

[304] ONS, 'Business Population Estimates 2018,' 2018, https://www.gov.uk/government/statistics/business-population-estimates-2018.

[305] ONS 'Estimates of the population for the UK, England and Wales, Scotland and Northern Ireland', 2021 https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationestimates/datasets/populationestimatesforukenglandandwalesscotlandandnorthernireland

Figure 37: R&D roles in UK businesses by UK countries and English regions (2019)



Source: RAND Europe analysis of ONS data

However, this concentration may be, at least in part, due to a 'headquartering effect'. As employment data is typically based on the registered locations of companies, those with offices and employees spread across the UK may be under-represented.

7. Societal Impact

In addition to long-term economic impact, the ISCF also aims to contribute to a wider range of societal impacts, including impacts on health and wellbeing and the environment and sustainability. In this chapter, two sections consider the baseline situation with respect to:

- **Health and wellbeing:** Providing baseline evidence for the evaluation question: 'To what extent has the ISCF contributed to health and wellbeing benefits, including quality of life, life expectancy, reduced health inequalities and reduced healthcare costs?'
- **Environment and sustainability:** Providing baseline evidence for the evaluation question: 'To what extent has the ISCF contributed environmental and sustainability benefits, including reduced emissions, progress towards net zero and growth of the circular economy?'

We note that the analysis presented here provides a high-level picture of the UK landscape in terms of health and environmental sustainability, which will be revisited in phase 4 of the evaluation. However, the societal and environmental impact of the Fund will also be further explored through methods such as stakeholder impact workshops and case studies. The data presented here are intended to provide an overview of the context in which the ISCF was implemented. We do not expect to see the Fund delivering measurable progress across all these metrics – and indeed change in any of these would depend on a wide range of other contextual factors. However, we will explore the most relevant aspects in more detail based on the impacts of the Fund we identify at a later stage of the evaluation.

7.1. Health and wellbeing

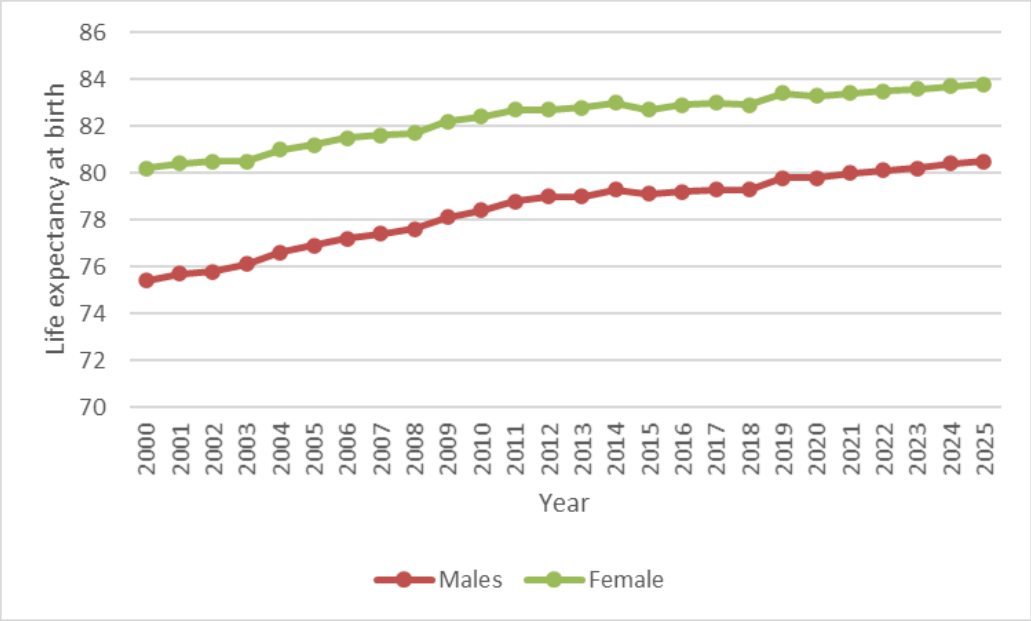
Evaluation question: To what extent has the ISCF contributed to health and wellbeing benefits, including quality of life, life expectancy, reduced health inequalities and reduced healthcare costs?

Key message: At baseline, data on health indicated static or declining performance across several key metrics including life expectancy, inequality and healthcare costs.

At baseline, healthy life expectancy was stalling and starting to decline in the UK. Following a century of increases in life expectancy in the UK corresponding to advances in healthcare and other predictors of

health, increases in life expectancy began to stall in 2011 (Figure 38) and since 2020, in light of the Covid-19 pandemic, we have seen significant falls in life expectancy.[306]

Figure 38: Life expectancy at birth in the UK up to 2018, and projections for 2018 to 2025 based on 2018 data

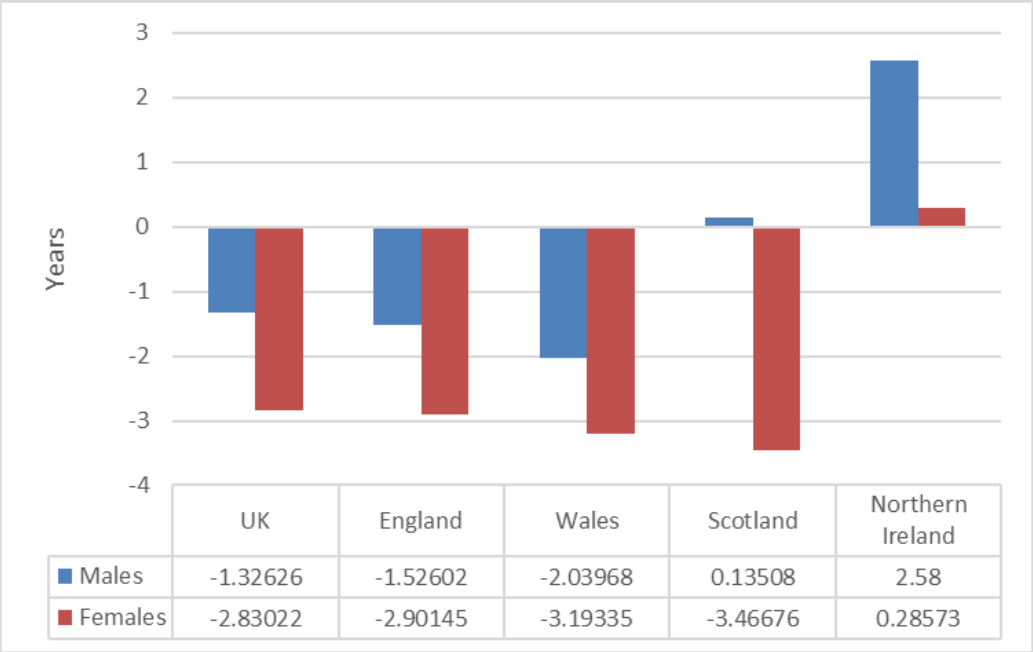


Source: RAND Europe analysis of ONS data.

Even prior to 2020, while life expectancy had been static, we saw decreases in healthy life expectancy across the UK as a whole and in most countries within the UK (with the exception of Northern Ireland), as shown in Figure 39. This increased morbidity, alongside broadly flat life expectancy, suggests an increasing burden of ill health, and indeed this is reflected in increased healthcare costs as explored further below.

[306] Jose Manuel Aburto et al., 'Estimating the Burden of the COVID-19 Pandemic on Mortality, Life Expectancy and Lifespan Inequality in England and Wales: A Population-Level Analysis,' *Journal of Epidemiology and Community Health* 75, no. 8 (August 1, 2021): 735, https://doi.org/10.1136/jech-2020-215505.

Figure 39: Change in healthy life expectancy in the UK (2009–11 to 2017–19)

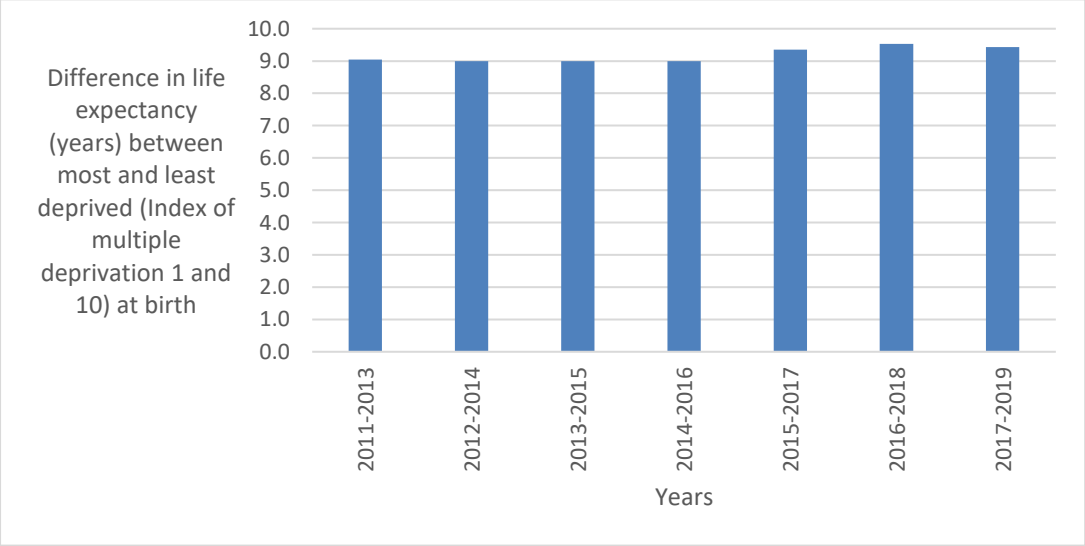


	UK	England	Wales	Scotland	Northern Ireland
Males	-1.32626	-1.52602	-2.03968	0.13508	2.58
Females	-2.83022	-2.90145	-3.19335	-3.46676	0.28573

Source: RAND Europe analysis of ONS data.

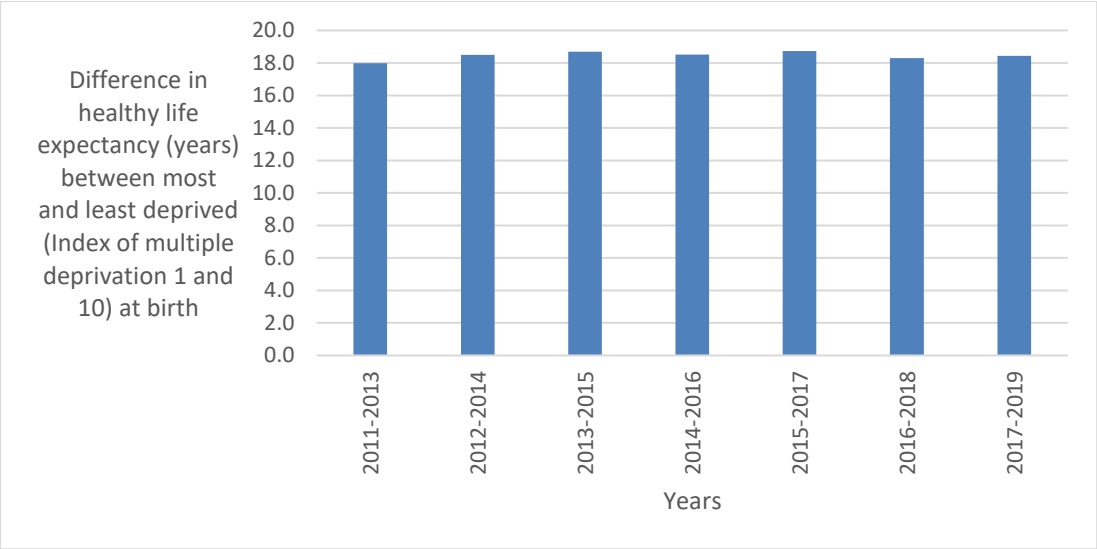
Health inequality was largely unchanged over the preceding decade. In 2018, health inequalities had also been broadly static over the preceding decade, with a difference in life expectancy of around nine years between the most deprived and least deprived decile of society (based on an index of multiple deprivation) (Figure 40), and an even larger disparity of around 18 years in healthy life expectancy (Figure 41).

Figure 40: Difference in life expectancy between most and least deprived groups in the UK (2011–2019)



Source: RAND Europe analysis of ONS data

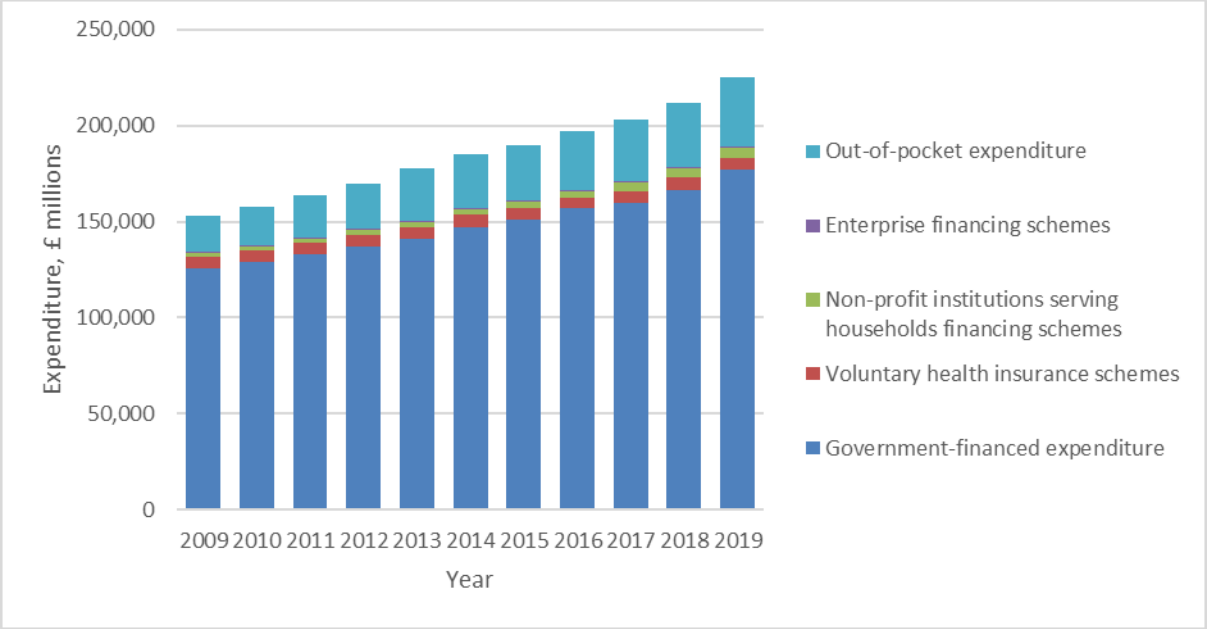
Figure 41: Difference in healthy life expectancy between most and least deprived groups in the UK (2011–2019)



Source: RAND Europe analysis of ONS data

Healthcare costs were growing. Reflecting increased morbidity, healthcare costs had grown by 47 per cent between 2009 and 2019 (Figure 42), with government (NHS) costs in particular increasing by 40 per cent.

Figure 42: Healthcare costs in the UK (2009–2019)



Source: RAND Europe analysis of ONS data. Note costs are in nominal terms.

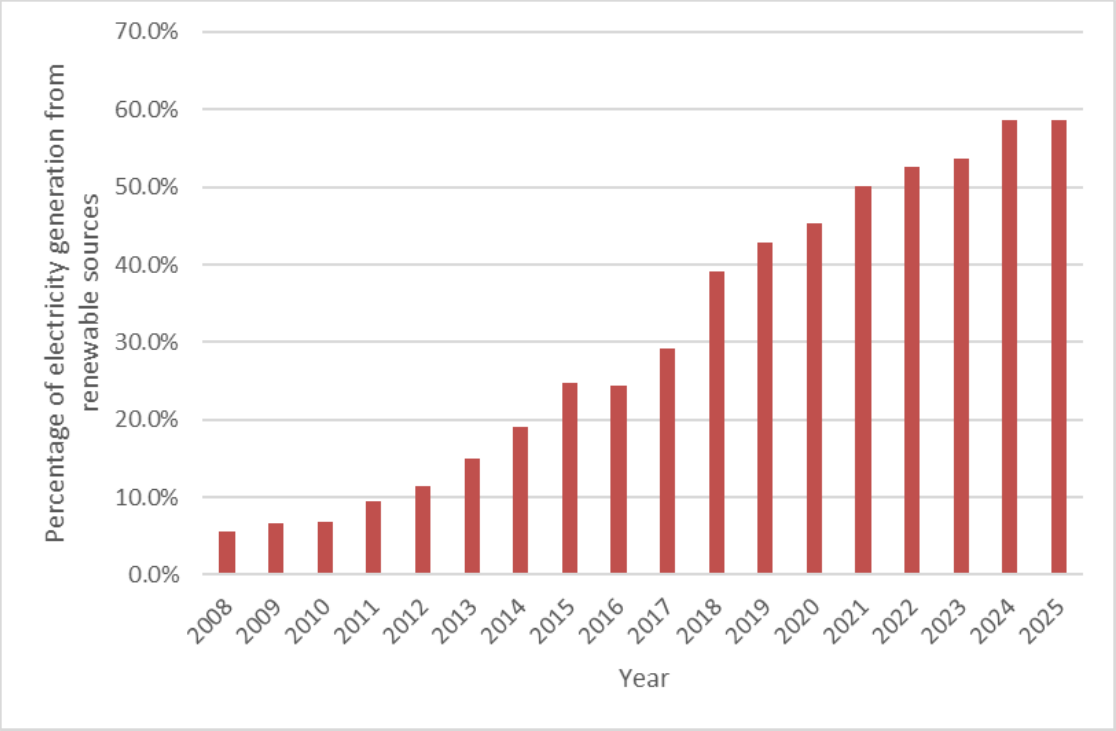
7.2. Environment and sustainability

Evaluation question: To what extent has the ISCF contributed environmental and sustainability benefits, reduced emissions, progress towards net zero and growth of the circular economy?

Key message: At baseline, environmental and sustainability issues were already on the agenda, but progress had been mixed, with GHG emissions still relatively flat. ISCF Challenges are targeting some of the key sectors identified as having high emissions at baseline.

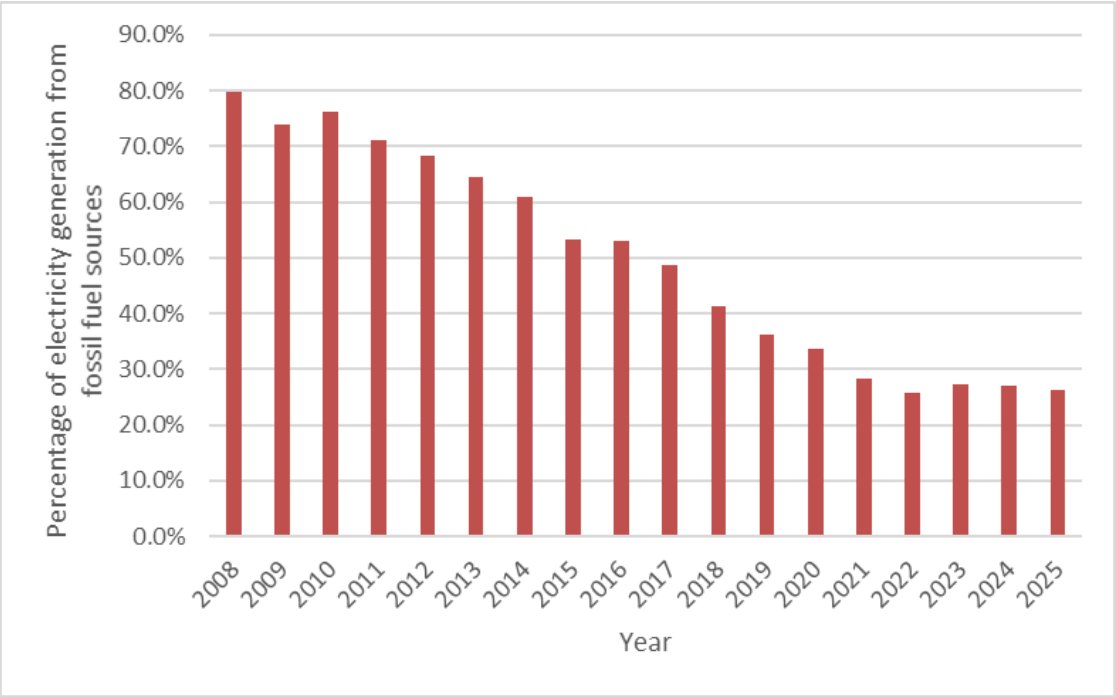
At baseline, environmental issues were already on the agenda and progress had been made. By 2018/19, the UK had already seen trends towards addressing environmental issues. In particular, there had been significant growth in renewable energy which had risen from 6 per cent to 39 per cent of the UK's electricity supply between 2009 and 2019 (Figure 43). Overall consumption of electricity fell by 17 per cent between 2008 and 2018, and the proportion of electricity coming from direct use of fossil fuels had declined from 79 per cent in 2008 to 41 per cent in 2018 (Figure 44).

Figure 43: Proportion of electricity from renewable sources in the UK, data from 2008–2018 and projections 2019–2025 based on 2018 data



Source: RAND Europe analysis of ONS data

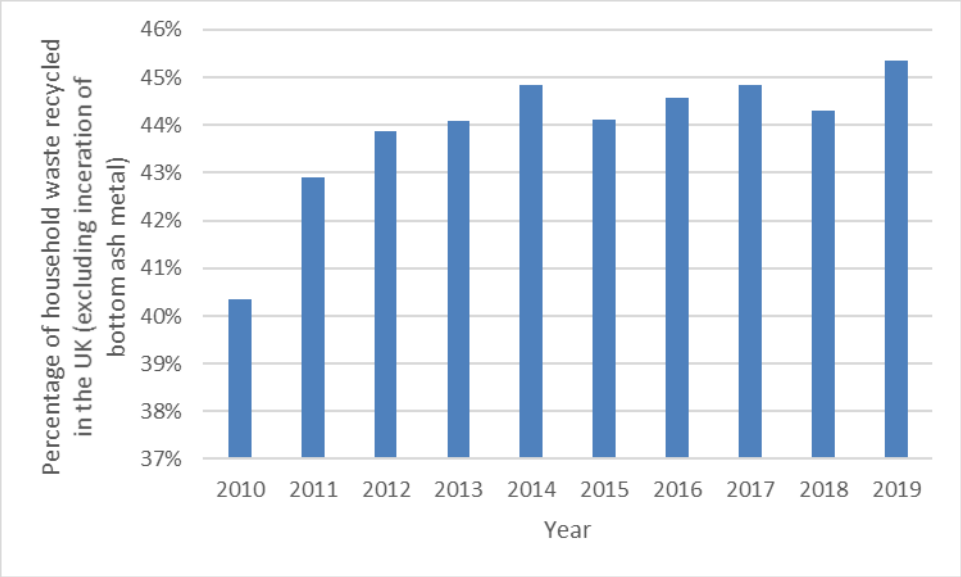
Figure 44: Proportion of electricity from fossil fuels in the UK, data 2008–2018, projections 2018–2025 based on 2018 data



Source: RAND Europe analysis of ONS data

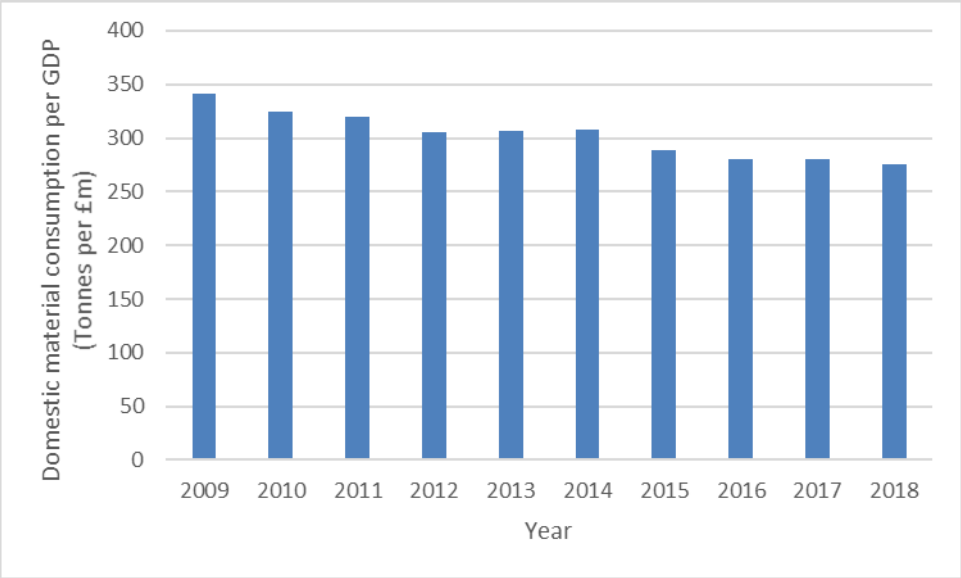
There had also been modest increases in the proportion of household waste recycled, from 40 per cent in 2010 to 45 per cent in 2019 (Figure 45), and reductions in material consumption, which fell by 19 per cent relative to GDP between 2009 and 2018 (Figure 46).

Figure 45: Proportion of household waste recycled in the UK (2010–2019)



Source: RAND Europe analysis of ONS data

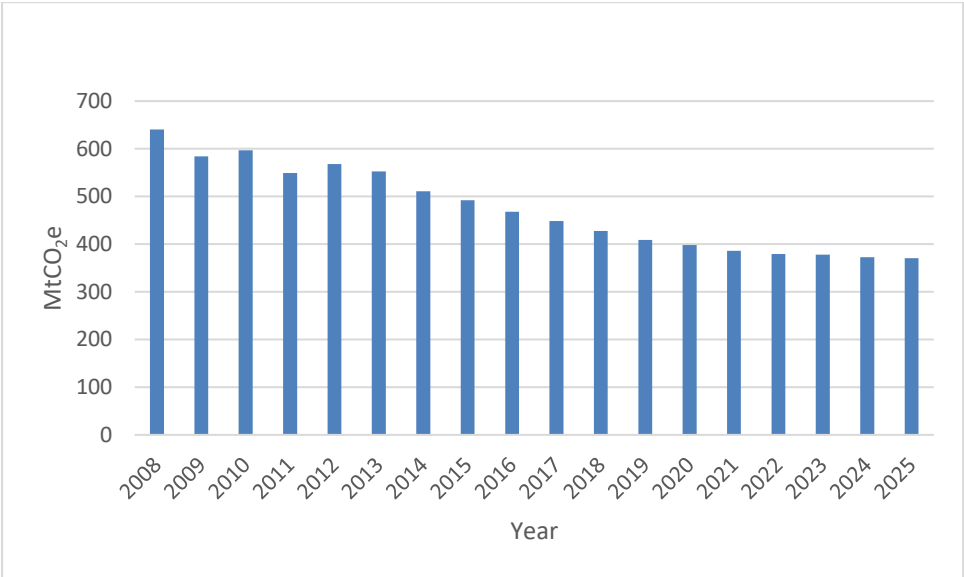
Figure 46: Domestic material consumption in the UK (2019–2018)



Source: RAND Europe analysis of ONS data

GHG emissions were still relatively flat despite these efforts. Despite these efforts, and the increase in renewables, overall GHG emissions were relatively flat, though decreasing by 17 per cent between 2009 and 2019 (Figure 47). In 2018, net zero was not yet on the agenda, but it was clear that the UK was not on track to make substantial reductions in emissions given trends.

Figure 47: UK GHG emissions, data 2008–2018 and projections 2019–2025 based on 2018 data

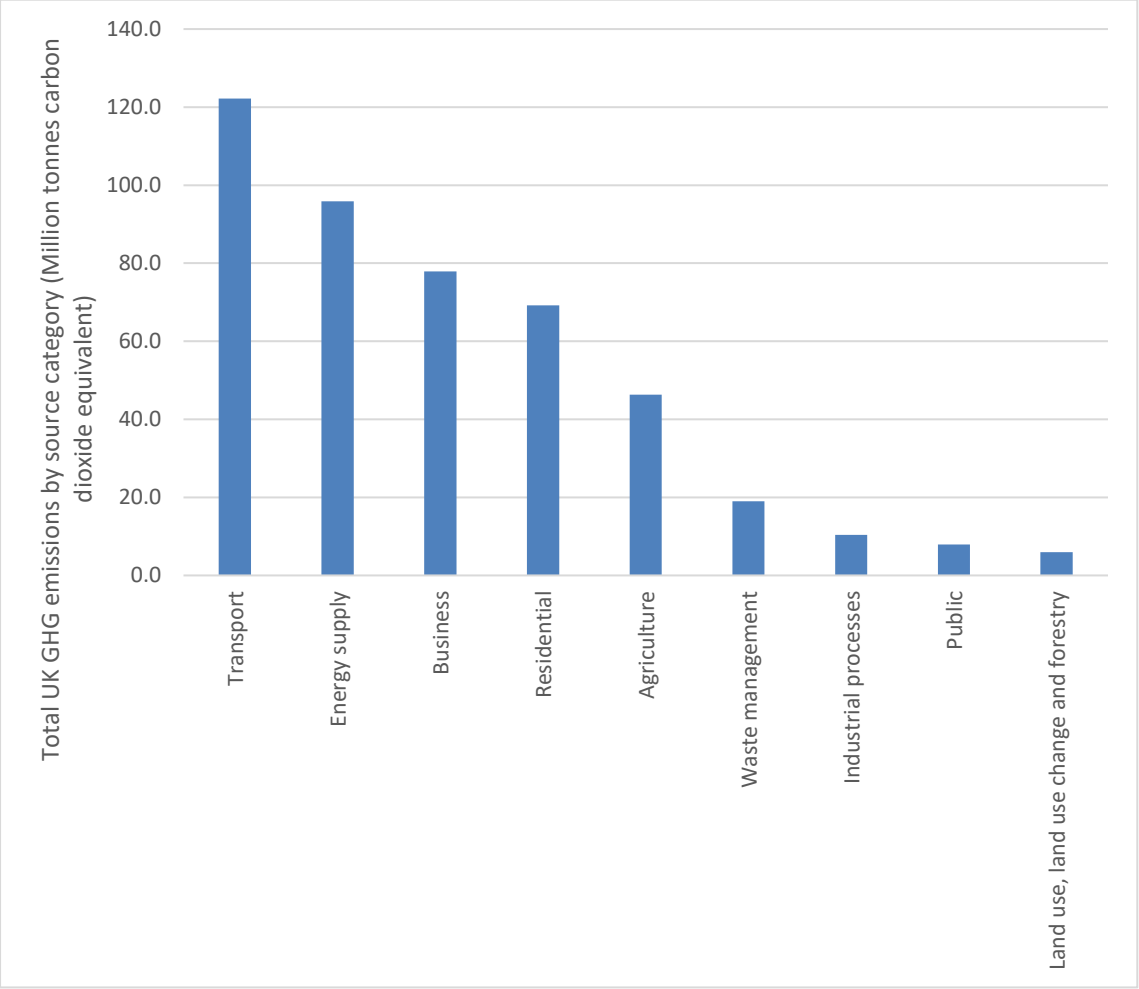


Source: RAND Europe analysis of ONS data

At baseline, it is clear that some Challenges are associated with disproportionately polluting industries (by design). In 2018, several industries can be identified as having particularly high emissions and several

of these – notably manufacturing, transport and energy – are specifically targeted by ISCF Challenges (Figure 48). For example, as of 2014, the built environment accounted for 42 per cent of the UK's total carbon footprint, with roughly 5.8 per cent of this total footprint embedded through new construction.[307] Similarly, all foundation industries have higher emission intensities than manufacturing and the wider non-financial economy.[308] Within certain industries too, one can see that certain organisations and regions have a disproportionately high carbon footprint: in the Industrial Decarbonisation Challenge at baseline, six industrial clusters accounted for 31 per cent of UK industrial emissions.[309]

Figure 48: Total greenhouse gas emissions by source in the UK (2019)



Source: RAND Europe analysis of ONS data

However, given the different metrics and indices of the different challenges, establishing cross-Fund lessons regarding environmental impact at baseline is challenging. A summary of different measures of baseline environmental impact across Challenges is provided in Table 13. However, a cross-cutting message is that many of the Challenges were directly targeted to address environmental issues – though several others (e.g.

[307] Frontier Economics, 'Transforming Construction Challenge - Baseline Report.'

[308] SQW, 'Transforming Foundation Industries: Industrial Strategy Challenge Fund Evaluation - Baseline Report.'

[309] Ipsos MORI, 'Industrial Decarbonisation Challenge - Baseline Report.'

in the health and healthcare sector, creative industries or data) are not directly intended to address environmental issues but may nonetheless have an impact in these areas.

Table 13: Key findings on environmental impact at baseline

Challenge	Key findings on environmental impact
Low Cost Nuclear[310]	• At baseline, the CO_2 emission intensity, defined as the ratio of CO_2 emissions from public electricity production, of the UKSMRs funded by the ISCF was 0.012 kg CO_2/kWh (including embodied emissions).
Industrial Decarbonisation[311]	• At baseline, six industrial clusters accounted for 31% of UK industrial emissions. The average emissions intensity across clusters can be estimated at 0.89 ktCO_2/£.
Future Flight[312]	• Air transport services as a whole emitted 45 m tonnes of CO_2 in 2018, a figure that has remained relatively stable in recent years. Across the transport and storage industry as a whole, emissions amounted to 83 m tonnes of CO_2, in 2018.
Transforming Foundation Industries[313]	• The chemicals sector had the highest energy intensity among the foundation industry sectors at baseline at 141.1 terajoules (TJ) in 2018. Metals also had a relatively high energy intensity at 73.7 TJ in 2018.
Transforming Construction[314]	• As of 2014, the built environment accounted for 42% of the UK's total carbon footprint, with roughly 5.8% of this total footprint embedded through new construction. Estimates from the ONS in 2018 indicate that construction contributed 13.1 m tonnes of direct CO_2 emissions equivalent, c.2% of the UK total.
Smart Sustainable Plastic Packaging[315]	• At baseline, organisations operating in this sector had a 69%, 0.04% and 1.1% market share of plastic packaging that is recyclable, compostable and re-usable at baseline respectively. It was responsible for placing 2,371 kt of plastic packaging on the market. 37 kt of this plastic packaging was deemed 'problematic and unnecessary' at baseline. The UK recycled just under half of plastic in 2019 (48%).
Transforming Food Production[316]	• Agriculture still accounted for a significant share of UK emissions in 2019 (~12% emissions compared to 0.7% of GVA) with an emissions intensity ~17 times higher than the UK economy average.

Source: RAND Europe analysis of Challenge-level baseline reports

[310] RSM, 'Low Cost Nuclear Challenge Evaluation: Work Package 2: Baseline Report.'

[311] Ipsos MORI, 'Industrial Decarbonisation Challenge - Baseline Report.'

[312] Frontier Economics, BMG, and Frazer-Nash Consultancy, 'Future Flight Challenge - Baseline Report.'

[313] SQW, 'Transforming Foundation Industries: Industrial Strategy Challenge Fund Evaluation - Baseline Report.'

[314] Frontier Economics, 'Transforming Construction Challenge - Baseline Report.'

[315] Eunomia, 'Smart Sustainable Plastic Packaging Challenge Evaluation - Final Baseline Study.'

[316] SQW, 'Transforming Food Production Evaluation - Baseline: Overview Report.'

8. Barriers, enablers and trends

In previous chapters we have set out the baseline situation prior to the ISCF being established. This serves as a valuable comparison point for our evaluation. However, the Fund is not being implemented in isolation. There are a wide range of other factors, trends and interventions occurring in parallel that can contribute (or indeed inhibit progress) towards the aims of the Challenges and the Fund overall. Therefore, any comparison between the achievements of the ISCF and the situation at baseline also requires consideration of the wider factors that might have contributed to those outcomes. Monitoring and considering the wider factors around the Fund will be an ongoing task throughout the evaluation. This chapter sets out an initial baseline assessment of some key barriers and enablers that could support or inhibit the Fund's progress towards its aims. This is largely based on input from sector experts at baseline workshops and is structured into two main sections: internal barriers and enablers related to the structure and operation of the Fund and UKRI more widely; and broader external barriers and enablers in the wider political, social, economic and environmental context. Please note, as described previously, the evidence provided here is based on areas of broad consensus within each workshop. We have only included points where there was a general level of agreement between participants in the workshop, and where illustrative quotes are provided, these are intended to indicate the nature of the wider discussion. We do not include in this analysis viewpoints that were highly contested or expressed by only one workshop participant.

8.1. Internal barriers and enablers to ISCF progress

Key message: Some aspects of Fund design and implementation have limited the Fund's ability to deliver the intended impact in Challenge areas. These include the agility and flexibility of Challenges, the scale and timeline of funding relative to the scale of the Challenges, and management structures within UKRI.

Processes can be slow, and there is limited agility and flexibility for Challenges to adapt to changing context. In our workshop discussions, several participants highlighted issues around speed and agility of ISCF investments that could affect the ability of the Challenges to deliver and respond to a changing environment.[317] Participants raised concerns that the timeline for launching, selecting and implementing

[317] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

the Challenges were problematic – for example the length of time for approvals in funding investments.[318] This, it was suggested, could lead to delays in progress in an already limited timeline for the Challenges, and also risked industry looking to other opportunities for investment overseas. However, more significant discussion was around the limitations and rigidity of the business plans associated with specific Challenges.[319] This was particularly highlighted in the transport and space workshop[320], where one participant noted that: 'in the commercial world, every business case is underpinned by assumptions. If the assumptions change, we change the business case'.

The fact that Challenges are largely tied to the case specified at the outset and lack the flexibility to pivot when things change (e.g. in the context of Covid), was also highlighted as a significant issue in the health and healthcare baselining workshop.[321] It is worth noting that there is a difference between the business case and the associated delivery plan for each Challenge. Where changes in context mean the route to achieving the Challenge aims change, this would call for adaptations in the delivery plan, and adaptability here would be feasible. If the changes in context mean the business case, and intended aims of the Challenge are no longer relevant, this is more difficult to accommodate in the context of the agreement with UKRI and the use of public funds.

UKRI internal structures can be difficult to navigate and are felt by some to focus on research over innovation-related activities. Another potential barrier to progress highlighted in two of the workshop sessions relates to the structure and focus of UKRI.[322] Some participants in those workshops suggested that changing priorities and focus within the organisation risk knowledge being lost, and in particular that IUK being embedded within the wider UKRI structure presented challenges since UKRI as a whole is primarily research- rather than innovation-focused. One participant mentioned that changing staffing and organisation structures meant there was the risk of 'constantly reinventing the wheel'[323], while others highlighted a lack of appreciation of 'how different Challenges are compared to other UKRI and IUK interventions'.[324] Discussion in the baselining workshops on manufacturing and sustainability in particular suggested several participants had experienced difficulties in navigating the UKRI landscape and encountered barriers due to structures, specific interests and culture within parts of the organisation. Again, differences in approach between IUK and the Research Councils were highlighted as a contributing factor.

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[318] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[319] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[320] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[321] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[322] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[323] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[324] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

The amount of funding and timeline may not fully reflect the scale of the Challenges. A key issue highlighted across all sectors was the timeline for delivery of the Fund.[325] The scale of the Challenges was felt to be such that an investment over the timeframe of the Fund was not sufficient to achieve their objectives. This was highlighted as a risk in several ways. A key concern was that knowledge and learning will be lost, and networks not be maintained, once the Challenges finish. Participants raised the 'potential for lack of cohesion and things disappear as the Challenges end'[326], and that the Fund offered the 'ability to integrate things from applied research to development, an opportunity to knit things together… but by the time it works the Challenge will be over'.[327] It was also considered a risk to industry confidence to invest, since the funding is only for a limited time period[328], with one participant noting that 'we got this far in the past then government pulled the plug'.[329] The Challenges have specified timelines, however it was apparent in workshop discussions that many participants hoped that the Challenges would be extended beyond them. Underlying many of these concerns was a perception that government priorities had shifted, with the Industrial Strategy shelved and a focus on new avenues for investment in R&I (e.g. ARIA).[330]

Beyond the timelines, views on the scale of funding were more mixed. Some felt the ISCF was a substantial investment[331], but many also suggested that there was a 'mismatch between the scale of investment and the rhetoric'.[332] Again, a lack of clarity on future funding and continuation of the Challenges beyond their current incarnation was a concern, not just in terms of the length of time for progress but also the scale of investment needed to deliver on the intended goals.[333]

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[325] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[326] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[327] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[328] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[329] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[330] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[331] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[332] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[333] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

8.2. External barriers and enablers to ISCF progress

Key messages: We identify a range of wider factors that can support and inhibit the progress of the ISCF towards its intended goals that can be broadly clustered into five themes: Regulatory and policy environment; Public acceptability and ethical issues; Network of engagement across sectors; and Exogenous shocks (e.g. Covid-19 and the UK's departure from the EU).

Regulatory and policy environment: New and novel technological innovations are not likely to be adopted where there are significant regulatory barriers. Potential regulatory barriers were highlighted in several of the workshops.[334] For example, government focus on national energy systems – limiting ability to act at a local level – was highlighted as a barrier to the adoption for SLES.[335] However, it was also noted that the political environment has potential to act as a facilitator where policy is correctly aligned. The government's commitment to achieve net zero emissions by 2030 is highlighted as an example that drives activity across several relevant sectors.[336] These high-level policy directions were noted as potential facilitators of progress and as providing confidence in industry[337], however some participants also suggested that when there are more 'certainties in policy…you'll really get the whole thing moving'[338], implying the need for more concrete policies – for example, a clear climate change target for the nuclear industry –beyond wider direction and rhetoric.[339] Other policy areas highlighted include the publication of the National Space Strategy[340], the Innovation Strategy[341] and structural changes in the NHS.[342] Broadly, the regulatory and policy context is highlighted across Challenges as a changing and critical factor in the outcomes of the Challenges, and our evaluation of the Fund will need to take into account this potential influence – both positive and negative. Many important policy priorities and changes are likely still to emerge, so this changing landscape will need to be monitored over the course of the evaluation.

Public acceptability and ethical issues: An important factor highlighted particularly for the health and healthcare Challenges[343] (but also noted for energy Challenges[344]) is the public acceptance of new technologies and solutions and, linked to this, any ethical issues around those new approaches. For example,

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[334] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[335] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[336] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[337] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[338] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[339] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[340] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[341] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[342] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[343] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[344] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

ethics are an issue around the use of AI in healthcare contexts. More widely, public perceptions of the use of health data, including for commercial purposes, can be a barrier to the development of new approaches based on health data, and potentially also a risk to inclusivity. This can also expand beyond health data considerations to wider healthcare interventions that typically have considerations around public acceptance, spanning topics from the role of government compared to individual responsibility and concerns around end of life care.[345] Across these issues in health – and potentially in other areas[346] – there may be differences between what is acceptable to society and what industry or the public sector (e.g. the NHS) consider progress. Therefore, public perceptions and values can be a barrier to adoption and can also change in response to wider economic, social, political and other changes.

Network of engagement across sectors: Across all sectors, the engagement of key stakeholders was identified as an important factor that can influence the extent to which Challenges will be able to deliver on their objectives.[347] Where Challenges were able to access a cohort of experts across key groups – government, industry and academia – from the outset, this was seen as a significant enabler for the design, set-up and early operation of the Challenge.[348] Focal points, or hubs, around which the field can coalesce, were also noted as a key enabler of progress. One example highlighted was WRAP (the Waste & Resources Action Programme), a charity focused on resource efficiency, which manages relationships between the supply chain and academics, and helps businesses and others to navigate the often complex landscape of funding and actors.[349] Individuals who can act as advocates and who have access to key decisionmakers were also highlighted as playing an important role in progress.[350]

Several key stakeholders are also highlighted as important for effective progress of the Challenges. In health, engagement with clinicians was noted as critical for deployment into clinical practice.[351] Across several sectors, engagement with policymakers is considered critical[352], and particularly in the baselining workshop on energy, this was highlighted as a barrier to progress for several Challenges. The particular issue raised was that there is no clear contact point within government with the knowledge, capability and resources to take forward and implement learning, and no clear mechanism to transfer that learning. This is due to the structures within key government agencies (e.g. BEIS, Ofgem) and a lack of alignment between policy teams. Similar challenges in the transfer of knowledge into government were also highlighted in the baselining workshop on manufacturing and sustainability. Here, a particular challenge was the cross-cutting

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[345] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[346] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[347] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[348] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[349] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[350] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy.'

[351] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[352] 'ISCF Fund-Level Evaluation: Baselining Workshop on Energy'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

nature of issues related to food and food production, which do not sit wholly within any one government department.

The need for 'an educated and aware investment community'[353] was also highlighted as a potential enabler. Across several sectors the need to raise investor awareness around new technologies was raised, alongside the opportunity presented by harnessing private investment and potentially de-risking a significant amount of private capital.[354]

Exogenous shocks: Over the course of the Fund so far there have already been several exogenous shocks that have impacted on sectors relevant to the ISCF. Most notable of these have been Brexit and the Covid-19 pandemic, but there have been others, such as a significant rise in energy prices, affecting not just the energy sector but also those working in energy-intensive industries such as in manufacturing.[355] Experiences of these and their impacts have been mixed, both across and within sectors.

The Covid-19 pandemic has presented both barriers and opportunities for progress of the ISCF. The experience has influenced public attitudes, increasing the value placed on scientific expertise[356] and also increasing willingness to engage with digital technologies and openness towards data sharing in some contexts.[357] The pandemic is seen to have been a driver of innovation in some sectors – including services and robotics[358], and even in aviation, which Covid-19 has severely impacted as a sector, while also changing the market, opening up opportunities for smaller businesses to engage and driving innovation to address the difficult market context.[359] The pandemic could also potentially drive an increase in investment in research infrastructure in some areas (e.g. health). Barriers due to the pandemic were also identified, most notably in terms of furlough, which has resulted in delays in progress in some cases.[360]

The UK's departure from the EU similarly has had mixed impacts on the implementation of the Fund so far. Barriers are largely around access to skills[361] and supply chain logistics[362], however advantages are also identified in terms of the drive to develop a more resilient, re-shored supply chain and promote inward investment.[363]

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[353] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[354] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare'; 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data'; 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[355] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[356] 'ISCF Fund-Level Evaluation: Baselining Workshop on Health and Healthcare.'

[357] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[358] 'ISCF Fund-Level Evaluation: Baselining Workshop on IT and Data.'

[359] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[360] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[361] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

[362] 'ISCF Fund-Level Evaluation: Baselining Workshop on Manufacturing and Sustainability.'

[363] 'ISCF Fund-Level Evaluation: Baselining Workshop on Transport and Space.'

9. Concluding remarks and next steps

We have set out the picture regarding to performance at baseline across several key areas which we intend to assess in the Fund-level evaluation of the ISCF. We see some common themes but also significant variation in some of the aspects assessed by sector and by Challenge. However, taking a wider perspective, we can see some key messages emerging.

We observe that the baseline conditions we have identified differ by Challenge, in large part reflecting the issues those Challenges were aiming to address. In most cases, these aren't solely a lack of technological innovation (though this typically plays a role in the solution, at least in part) but rather relate to market failures which require collective action and government investment to correct. Most of the Challenges have been established to address issues where there is no motivation for individual companies to act, but where innovation would be a driver for progress for businesses and for society.

We can identify several broad types of baseline condition. Several of the Challenges have been established in areas needing increased coherence and support for the development of a new sector or a focal area that can capitalise on existing strengths and capabilities in the UK that previously lacked targeted investment or a focal point for key actors in the field to coalesce around and build networks and connections (e.g. Medicines Manufacturing, Transforming Foundation Industries). Other Challenges reflect the need for collective action to radically rethink the underlying technology in a sector, but where it would not be feasible or beneficial for any one company to do that unilaterally (e.g. Digital Security by Design). Others are targeted where there are regulatory or business model barriers to progress in adoption or realisation of the full potential of a new innovation, and hence collective action is needed to rethink and remove those barriers (e.g. Prospering from the Energy Revolution).

There are other examples, and these categories are not mutually exclusive, but they point to potential differences in the baseline conditions by Challenge depending on the type of market failure and the reason for intervention. Common to all these issues, however, is the need to bring key actors together and act collectively to overcome barriers and foster collaboration. These are reflected in some of the cross-cutting themes that we can identify that resonate broadly across most contexts, such as **a lack of connections and interactions between key stakeholders** (whether between businesses, or with policymakers or other stakeholders); **a need for additional or, more often, specifically targeted investment to address a key challenge or issue; the lack of a focal point around which a sector or field can coalesce**; and **a strong academic base that had not always been able to reach its full innovative and economic potential.**

This baseline assessment has several implications for the next steps in the evaluation.

Given that the baseline picture varies across contexts – depending on the nature of, and reasons for, the Challenge, as set out above – **it is difficult to identify a unified and universally applicable baseline picture for the Fund as a whole**. Rather, we can observe some broad trends and some characteristics that apply across several Challenges where there are similarities in aim and context. This may have implications for our overall assessment of the performance of the Fund since we do not have one universal baseline against which the Fund as a whole can be compared. Similarly, given the variability of the baseline data from the Challenge-level reports, we have largely taken a qualitative rather than quantitative approach to baselining indicators at the Fund level. We also note that although we have been able to establish some of the wider factors that may influence progress of the Fund from baseline, this will require further ongoing monitoring and assessment over the course of the evaluation since new factors and drivers may emerge. For example, at the time of the Fund being established it would have been difficult to predict the emergence of the Covid-19 pandemic and its implications. This complex, partially qualitative and evolving picture is what we would expect to see for a complex, multifaceted fund such as the ISCF, and further supports our decision to take a contribution analysis-based approach to the evaluation, and also reinforces the need to consider other comparison points as well as this baseline assessment as part of our review of the performance of the Fund, as planned.

9.1. How baseline data will be used within the impact evaluation

The baseline data presented in this report will be used – alongside other baseline data to be collected (see Section 2.3) – as a comparison point for the final impact evaluation. We will look to see how the picture has evolved across these different themes and where there is evidence of progress across the ToC towards Fund aims. In some cases, our assessment of progress against the baseline will be quantitative in nature. For example, data on the baseline situation of ISCF businesses collected as part of the econometric analysis (e.g. data on employment and turnover) will be compared against longitudinal data on firms during the period of receiving ISCF support. Combined with analysis of a counterfactual group of businesses, this analysis of business performance over time will provide a set of quantitative measures of progress against the baseline position. There are also ways in which the present baseline report has provided quantitative measures against which future impacts can be assessed. Scientometric analysis of publications output of individuals funded through ISCF Challenges at baseline, for example, has provided citation metrics that can be compared to later data to assess impacts of ISCF support. (In any such quantitative assessment of impact, of course, it will be important to consider the extent to which the observed impacts are indeed a result of ISCF support).

While providing quantitative measures in some cases, as noted above, in many cases, our overall baseline assessment is qualitative; the complexity and variability of the Challenges preventing amalgamation of this data into an overall quantitative baseline measure. Importantly, our qualitative assessments do include quantitative metrics and data relevant to individual ISCF Challenges. In this report, we have used these individual quantitative data to develop an overarching qualitative assessment of the baseline landscape. As we proceed to the impact evaluation, these qualitative assessments of the overall baseline landscape will be used as context with which to assess progress of the Fund, while also considering the progress of individual Challenges in relation to their more specific, in some cases quantitative, baseline measures.

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