UK INSTITUTE FOR TECHNICAL SKILLS & STRATEGY

frontier economics

The Technical Skills Landscape in the Digital and Technologies Sector

A report for the UK Institute for Technical Skills & Strategy

11 February 2026

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1 Executive summary

1.1 Policy context

In June 2025, the UK Government set out its Modern Industrial Strategy, a ten-year plan to boost business investment and accelerate the growth of future-facing industries in the UK. Central to this strategy is the identification of eight priority sectors (the IS-8) with the highest future growth potential. One of the IS-8 sectors identified was Digital and Technologies, which contains six frontier industries:

- Advanced connectivity technologies (ACT)
- Artificial intelligence (AI)
- Cyber security
- Engineering biology
- Quantum technologies
- Semiconductors

A key theme arising from the Industrial Strategy consultation responses was the importance of enhancing skills and accelerating access to talent across the IS-8 sectors (DBTa, 2025). While the UK has strengths in this area, skills shortages and skills development were identified as potential barriers in these industries.

Given the critical role the Digital and Technologies sector and its six constituent frontier industries play in the Modern Industrial Strategy, it is essential for the UK Government to understand the technical skills landscape in each of these industries, so that any barriers preventing the sectors from realising their full potential can be addressed.

1.2 Aims and objectives

The UK Institute for Technical Skills & Strategy (UK ITSS) has commissioned Frontier Economics to assess the technical skills landscape for each of the six frontier industries. The primary objective of this study is to assess the current state of technical skills in each frontier industry, and how demand for technical professionals may change in the future.[1] Specifically, we analyse:

- The economic contribution of each frontier industry;
- The workforce demographic profile within each frontier industry; and
- The current technical skills landscape and how this is expected to change in future.

[1] In previous UK ITSS reports, technical professionals were referred to as technicians.

The role of universities, research institutes, and policymakers in helping address any gaps identified in the technical skills landscape are also explored as secondary objectives.

To address the objectives, we conducted:

- **A rapid evidence assessment:** This identified what is currently known about the technical skills landscape in each frontier industry, how this might change in future, and the role of universities and research institutes. A gap analysis was then conducted, highlighting where evidence is of poorer quality or missing. These findings were then tested in an interim workshop with policymakers, informing the focus for the second part of the study.
- **Qualitative engagement:** Building on the findings from the rapid evidence assessment, a three-part programme of qualitative engagement with technical professionals, universities, research institutes, and industry bodies across each frontier industry was conducted to address (where possible) the identified evidence gaps. In total, 31 stakeholders were engaged. This included representatives from all six frontier industries to ensure a range of perspectives were heard.

Insights from the rapid evidence assessment and qualitative engagement were then triangulated for each industry to identify remaining evidence gaps and inform the development of policy recommendations. The final findings and policy recommendations were then tested with policymakers in a second workshop.

1.3 Economic contribution of frontier industries

Figure 1 Evidence gaps and priorities for intervention

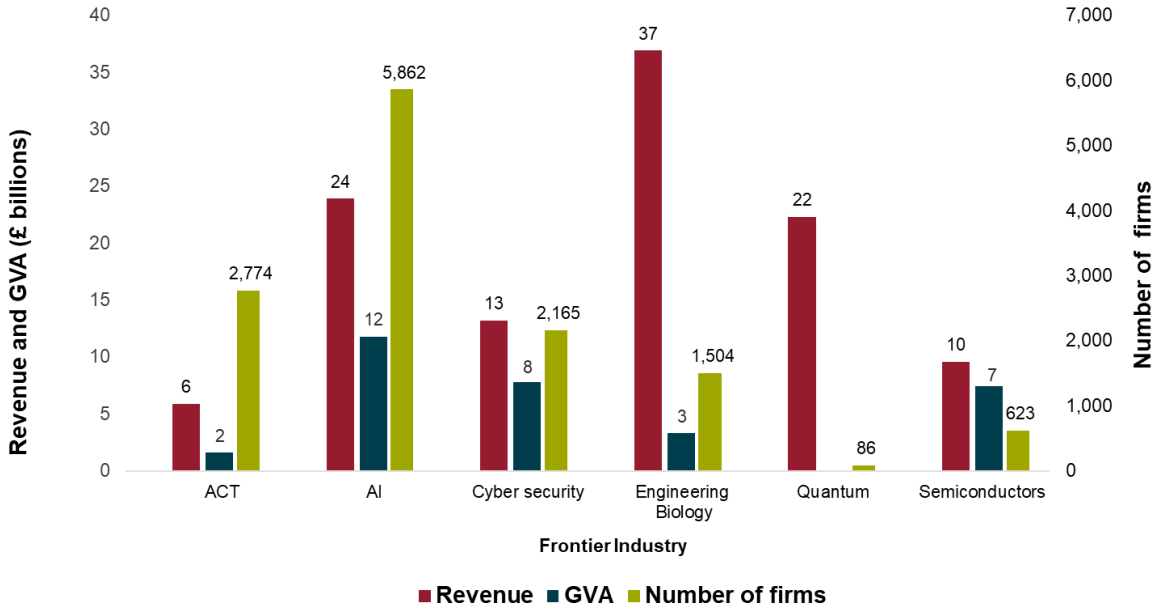
Source: Frontier Economics

The size of the six frontier industries vary significantly, with Figure 2 summarising the best available estimates of revenue and economic contribution for each. Overall, engineering biology and AI are the largest industries by revenue, followed by quantum technologies, cyber security, semiconductors and ACT. In terms of gross value added (GVA), AI and cyber security are the largest, followed by semiconductors, engineering biology and ACT. GVA estimates are not available for quantum technologies.

The Department for Science, Innovation and Technology's (DSIT's) sectoral studies provide workforce estimates for the six industries, although these are not specific to technical professionals. These are presented in Figure 3 below. Differences in methodology between DSIT and alternative sources do, however, produce markedly different employment estimates. For instance, The Data City (2025) estimates employment in the AI industry at 380,525, whereas DSIT (2025a) reports a figure of 86,139. Across the industries where both sources provide data (AI, cyber security, engineering biology, quantum and semiconductors), The Data City's employment estimates are, on average, around 4.6 times higher than those reported by DSIT.

Overall, across all industries, reported figures vary widely due to inconsistent definitions, methodologies, and data sources, limiting comparability.

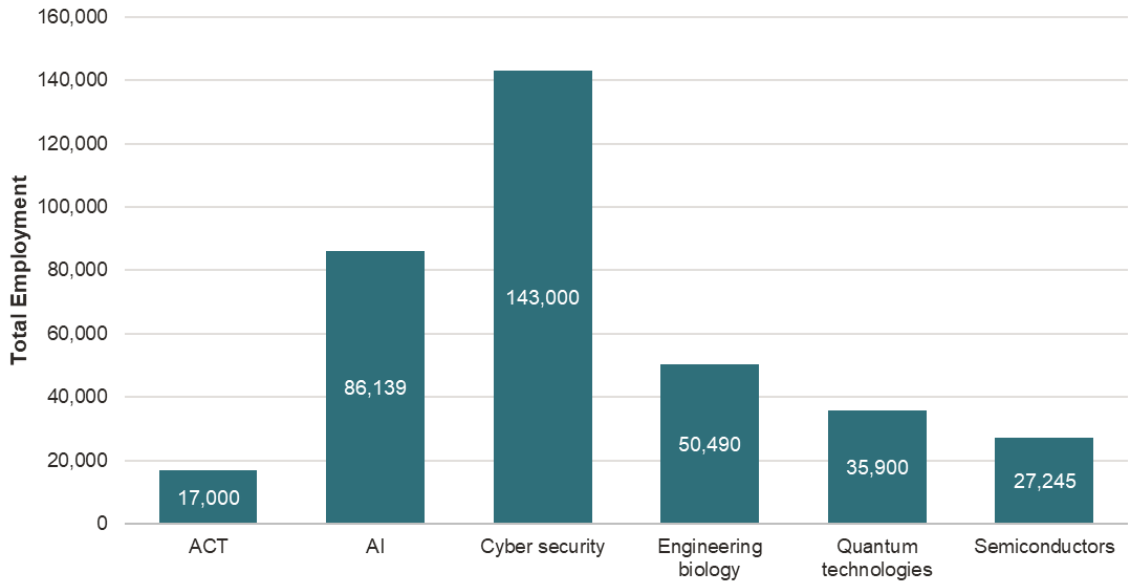
Figure 2 Estimates of the size and economic contribution of each frontier industry



Source: *DSIT (2025) ACT Market Scoping Analysis 2025; DSIT (2025) Artificial Intelligence sector study 2024; DSIT (2025) Cyber security sectoral analysis; DSIT (2025) Engineering Biology, Quantum Technology and Robotics and Autonomous Systems analysis; and DSIT (2024) Semiconductor sector study.*

Note: *ACT data is for 2024 (apart from the number of firms, which is for 2025); AI is for 2024; cyber security is for FY2024/25; semiconductors is for 2022; and engineering biology and quantum technologies for 2022/23. Estimates are not directly comparable across industries, as figures are derived from different data sources and methodologies. The figures reported for ACT reflect the contribution of core ACT firms only (i.e. excluding hybrid firms). GVA estimates are not available for quantum technologies.*

Figure 3 Employment in frontier industries



Source: *DSIT (2025) ACT Market Scoping Analysis 2025; DSIT (2025) Artificial Intelligence sector study 2024; DSIT (2025) Cyber security sectoral analysis; DSIT (2025) Engineering Biology, Quantum Technology and Robotics and Autonomous Systems analysis; and DSIT (2024) Semiconductor Workforce Study.*

Note: *ACT and AI data are for 2024; cyber security is for FY2024/25; semiconductors is for 2025; and engineering biology and quantum technologies are for 2022/23. Employment estimates are not directly comparable across industries, as figures are derived from different data sources and methodologies.*

Given these findings, we make three policy recommendations relating to the economic contribution (EC) of frontier industries (EC1 to EC3):

EC1 Standardise, where possible, the approach to data collection, modelling assumptions, taxonomies, and timeframes across studies. This could include developing new or adapted SIC and SOC classifications (or potentially hybrid options). This will minimise ambiguity and enable more accurate comparisons across industries.

EC2 Gather data to provide detailed breakdowns of the number of technical roles and their type in each industry. This would enable more detailed analysis of skills needs in these industries.

EC3 Provide a regional breakdown of economic statistics (revenue, number of firms, GVA, number of employees). This breakdown should be at the ITL1 level as a minimum, or in line with the Skills England's (2025a) specified areas in their Local Skills

Improvement Plans.[2,3] This will help identify and track industry clusters as they develop over time.

1.4 Demographic profile of frontier industries

Figure 4 Evidence gaps and priorities for intervention

Source: Frontier Economics

All six frontier industries are underpinned by a workforce which follows higher education pathways, with a particular focus on STEM disciplines. A recurrent finding is the persistent gender imbalance: on average, over 78% of roles relevant to these industries are held by men. Evidence on age patterns suggests contrasting dynamics across industries: semiconductors and ACT face replacement pressures, whereas AI has a comparatively young workforce. Across AI and semiconductors, international talent is an important component of labour supply.

Despite these broad patterns, the available data on workforce demographics remain fragmented and inconsistent. The Jobs and Skills Dashboard (2024) provides the only cross-industry dataset, but it has notable limitations: it reports on roles relevant to each industry rather than their actual workforce, draws on indicators from different years, and lacks coverage for cyber security specifically.

Data on other aspects of diversity beyond gender, age and education, such as sexual orientation and socioeconomic background are not reported, and there is minimal coverage of disability, neurodiversity, and ethnicity across industries. Where figures do exist, they indicate persistent under-representation of ethnic minorities and disabled people, particularly at senior and leadership levels. Neurodiversity is better captured in cyber security than elsewhere, but comparable evidence is lacking across most other frontier industries.

[2] ITL1 refers to the highest level of major socioeconomic regional breakdown, consisting of nine English regions (like London, South East, etc.) plus Scotland, Wales, and Northern Ireland.

[3] Skills England identify 'specified areas' for local skills improvement within the North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East, Greater London, South East and South West. For example, Cheshire and Warrington, Cumbria, Greater Manchester, Lancashire and the Liverpool City Region are specified areas in the North West.

Critically, there is almost no disaggregated demographic data for technical professionals, leaving their demographic characteristics poorly understood.

Amongst these demographic patterns, the qualitative engagement emphasised gender diversity as a high-priority area that policy makers should focus on. Potential solutions that were raised included:

- Intervening at an early stage in the education pipeline (i.e. GCSE level or before);
- Supporting widespread work experience opportunities;
- Implementing more inclusive language when engaging younger generations;
- Showcasing successful industry role models from a variety of backgrounds; and
- Increasing structural support through scholarships or funded programmes.

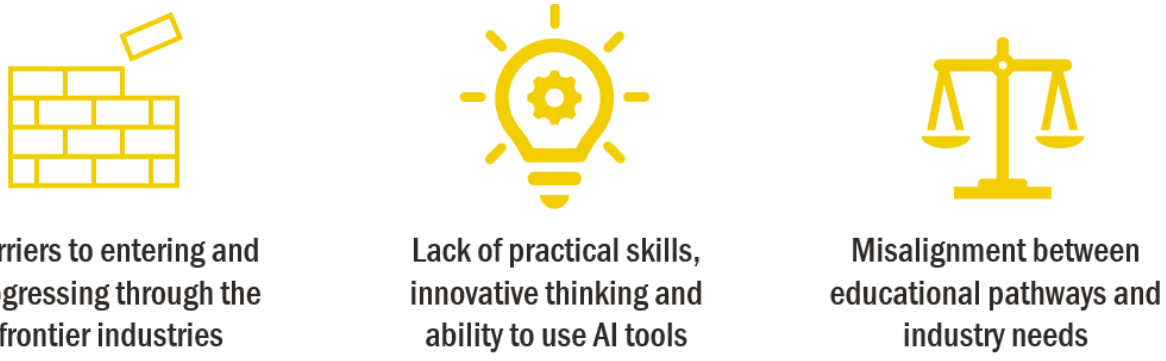
Given these findings, we make two policy recommendations relating to workforce demographics (D) within the frontier industries (D1 to D2):

D1 Develop a consistent dataset providing comparable demographic data across technical roles in frontier industries over time. This should include gender, but possibly other characteristics such as sexual orientation, ethnicity, age, disability, neurodiversity, and socioeconomic background. Enhanced workforce demographic data will improve the ability to track trends in the technical workforce, informing policy interventions across skills planning and research agendas.

D2 Steps should be taken to further explore the causes of gender imbalances and possible solutions. In particular, interventions should be aimed at younger students, after which it likely becomes more difficult to tackle these imbalances.

1.5 Current technical skill gaps in frontier industries

Figure 5 Evidence gaps and priorities for intervention



Source: Frontier Economics

Across all six frontier industries, there is consistent evidence of widespread and persistent technical skills shortages. These deficits span both entry-level and advanced roles, affecting technical professionals, engineers, and specialist researchers alike. The shortages are compounded in certain industries by an ageing workforce, with some industries noting a lack of succession planning and limited visibility of technical career routes. Existing studies tend to identify headline skill deficits but provide limited granularity on which specific occupations, qualification levels, or technical functions are most affected. Shortages disaggregated by role, information covering career progression, and workforce ageing and retirement are lacking.

A second recurring theme is the rapidly evolving nature of technical skill requirements. The convergence of technologies, particularly the integration of AI and automation, is changing the skills needed in the frontier industries. Across frontier industries, more robust, data-driven mapping of current and emerging skills needs is required, given the lack of a systematic mapping of current and emerging skills gaps.

In part, the shortage of technical professionals is driven by persistent, cross-cutting barriers to entering and progressing through the six frontier industries. In particular, the qualitative engagement identified a lack of awareness of technical roles in frontier industries and poor working conditions as restricting the supply of prospective technical professionals. It also identified regional elements to the skills shortages amongst the existing workforce, with uneven geographical support causing shortages to be more concentrated in certain parts of the UK.

Skills gaps are compounded by insufficient alignment between education and industry needs. Existing further and higher education provision does not yet fully match the skills needs in frontier industries. Cross-cutting gaps were reported in practical skills, innovative thinking and interdisciplinary capabilities, particularly in combining engineering with computing, AI, and data science. Apprenticeships, degree apprenticeships, and conversion courses appear under-utilised relative to demand.

Given these findings, we make seven policy recommendations relating to the current skills landscape (CS) within the frontier industries (CS1 to CS7):

CS1 Detailed and consistent information quantifying technical skills shortages and vacancies should be collected to enable policy responses to be effectively targeted. The data should be sufficiently granular to identify the specific occupations, qualification levels, skills and technical functions most affected. While the available evidence points to persistent skills gaps, their precise scale remains unclear.

CS2 A robust, data-driven mapping of current and emerging technical skills should be completed. While the qualitative engagement points to themes such as a lack of practical and applied skills, proactivity, innovative thinking, and proficiency with handling AI tools (which may be early places to focus), gaining a comprehensive view across industry is key.

CS3 A systematic analysis of retirement risks, succession planning, and supply of prospective technical professionals should be conducted for each frontier industry. By understanding workforce dynamics and future replacement needs, government can then proactively address potential challenges before they arise.

CS4 Steps should be taken to improve the pipeline of skills and awareness of technical routes early, before children start to specialise. This may help break down barriers and improve the supply of prospective technical professionals.

CS5 The working conditions of technical professionals should be improved. This includes potentially supporting improved pay, progression and job security of technical professionals in the higher education sector in particular.

CS6 Ensure there is a level playing field in funding and support across regions. The qualitative engagement indicated that developing regional skill clusters and talent pipelines, and supporting small and medium enterprise (SME) ecosystems beyond the Golden Triangle could help address this.[4]

CS7 Align educational pathways more closely with industry skill needs. This includes a stronger focus on developing students' practical skills, innovative thinking, and proficiency with handling AI tools.

1.6 Future technical professional shortages in frontier industries

Figure 6 Evidence gaps and priorities for intervention

Shortfall in technical professionals is estimated to rise between 10x and 65x by 2035

Skills relating to emerging technologies, such as AI, are expected to face the most significant shortages in the future

Source: Frontier Economics

The evidence across the frontier industries consistently highlights a current, pressing need for technical professionals. While there is some evidence on the current composition and characteristics of each industry's workforce, there remains limited understanding of how the demand and supply of technical professionals will evolve over time. To help address this

[4] The Golden Triangle refers to the area between London, Cambridge and Oxford.

evidence gap, high-level projections of how current shortfalls in technical professionals may evolve over the next ten years have been developed.

Projections were derived by combining data on current workforce size, the proportion of these which are technical roles, and vacancy rates for technical roles. Future employment demand for each industry was then projected under a low- and high-growth scenario. These growth rates reflect current forecasts for employment (low) and revenue growth rates (high) in each industry.

The results, outlined in Table 1, indicate that, without a significant expansion in the supply of technical professionals, existing shortfalls will continue to deepen across all frontier industries over the next decade. In absolute terms, the largest cumulative shortfalls are expected to be in the AI, cyber security, and semiconductors industries. By 2035, shortfalls of technical professionals are due to rise by a minimum of around 10 times in the low-growth scenario for the quantum technologies industry, or a maximum of around 65 times in the high-growth scenario for the AI industry.

Table 1 Estimated cumulative shortfall in technical professionals to 2035 in industry

Frontier industry	2025	2030	2035
ACT	0 - 100	100 – 700	300 – 1,500
AI	600	3,500 – 7,900	6,600 – 38,700
Cyber security	600 – 1,000	3,700 – 8,400	6,900 – 21,000
Engineering biology	300 – 600	2,000 – 5,800	3,700 – 17,000
Quantum technologies	200 – 500	1,000 – 5,500	1,900 – 20,700
Semiconductors	400 - 900	2,700 – 7,400	5,000 – 18,900

Source: *Frontier Economics*

Note: *The reported results are based on the low-growth, lower bound scenario and the high-growth, upper bound scenario. Numbers have been rounded to nearest 100.*

While there is limited published quantitative evidence on shortfalls in technical professionals across the frontier industries, where such evidence exists, the projections above are consistent with those. Despite being developed using the best available evidence, the projections are subject to a number of assumptions and data limitations.

The qualitative engagement confirmed that skills shortages in frontier industries are increasing. In particular, existing gaps in AI engineering, basic AI literacy, and AI appraisal skills were identified as likely to worsen without intervention. It was also highlighted that emerging technologies are advancing faster than formal qualifications, contributing to skills

shortages in the most cutting-edge areas of each frontier industry. Through the qualitative engagement, a number of potential solutions were suggested:

- Implementing short, targeted courses aimed at new entrants into the industries as well as existing technical professionals;
- Supporting industry-led training through apprenticeships and/or industry-led modules; and
- Increasing support for SMEs by providing access to affordable advanced computing resources, secure data spaces, experimental labs, and testbeds.

Given these findings, we make three policy recommendations relating to future skills shortages (FS) within the frontier industries (FS1 to FS3):

FS1 Periodic horizon-scanning should be undertaken to assess and quantify where technical skills shortages are likely to worsen or ease over time. Given the rapid pace of change in skills needs, an adaptable approach to policymaking in this area is likely to be essential.

FS2 Producing updated technical professional shortfall forecasts using more robust industry-specific data is advised. While all forecasts should be treated with a degree of caution, they are necessary to quantify the scale of intervention required. Forecasts should cover both academic and industry shortages.

FS3 Steps should be taken to ensure technical professionals are continuously trained in line with the emerging skill needs in each frontier industry. A particular focus should be on upskilling the workforce around the everyday use cases of AI, as well as the validation and appraisal of AI outputs. Providing opportunities for technical professionals to develop skills relating to proactivity and innovative thinking, and to learn practical and applied skills, is also key.

1.7 The role of universities and research institutes

Figure 7 Evidence gaps and priorities for intervention

Source: Frontier Economics

Across the six frontier industries, there is relatively limited industry-specific evidence on how universities and research institutes support technical skill development. There is even less evidence covering the current educational and professional pathways into technical roles in frontier industries, and the barriers technical professionals face when entering and progressing in each industry.

However, the available evidence on educational attainment and feedback from the qualitative engagement provides a strong indication of the key role that universities and research institutes play in training the technical workforce. Based on Jobs and Skills Dashboard (2024) data, roles relevant to the frontier industries are consistently more highly educated than the wider economy average:[5] between 63% and 73% of early-career workers across these industries enter via higher education routes, compared with just 40% across the wider economy. Doctoral and postgraduate education play a distinctive role in the quantum, engineering biology, and semiconductor industries, while AI and cyber security rely more heavily on undergraduate and master's-level provision. This pattern reinforces the pivotal role of universities as the current primary gateway into frontier industries and highlights their likely continued importance in sustaining the future pipeline of technical skills.

In most industries, evidence points to gaps between the skills taught in universities and those required in the workplace. In AI and cyber security, the evidence suggests this misalignment might reflect rapid technological change and an insufficient emphasis on applied problem-solving. In semiconductors and quantum, emerging evidence indicates the gap may be rooted in limited practical training opportunities before entering the workforce.

Stakeholder feedback from reports across multiple industries, as well as our own qualitative engagement, emphasised the value of structured engagement between universities and industry to ensure training remains relevant. Work placements and degree apprenticeships were recognised as effective mechanisms for developing job-ready graduates, yet provision was highlighted as uneven and often concentrated in specific disciplines (for example, physics and engineering).

Several reports also highlighted the lack of vocational or hybrid qualifications bridging technical and higher education routes. The qualitative engagement generated a range of proposed approaches to address these issues:

- Supporting industry-sponsored apprenticeships for university students;
- Linking Centres for Doctoral Training (CDT) courses with real-world datasets to improve skills around management of large data infrastructure;
- Providing short, targeted courses aimed at upskilling new and existing technical professionals in key areas; and
- Supporting training for SMEs, who are often at the cutting-edge of new technologies.

[5] The Jobs and Skills Dashboard (2024) does not include data for the cyber security and ACT industries. As a proxy for these industries, we use data provided for the "Digital and Computing" and "Future Telecommunications" groups instead.

Given these findings, we make two policy recommendations relating to the role of universities and research institutes (RU) within the frontier industries (RU1 – RU2):

RU1 University curricula should be better aligned with industry needs. This includes providing, where possible, increased exposure to more practical and applied environments. Interventions should support collaboration between universities, CDTs and industry.

RU2 Alternative pathways for technical professionals should be investigated alongside higher education options. This could include leveraging T-Levels, V-Levels or apprenticeships funded through the Growth and Skills Levy.

1.8 Reflections on future policy

The rapid evidence assessment and qualitative engagement demonstrate that the UK has clear strengths across the six frontier industries in the Digital and Technologies sector. Persistent, and likely growing, shortages in technical skills are, however, acting as a key barrier to their continued success. The government has recognised this challenge, with skills now a high-priority policy area. In 2025 alone, this included the establishment of Skills England, the publication of the Post-16 Education and Skills White Paper, and the release of the UK Standard Skills Classification, among many other initiatives.

Our policy recommendations build on this work by identifying the most pressing evidence gaps and setting out how these could be addressed. They are informed by detailed discussions with technical professionals, industry bodies, universities, research institutes and policymakers, alongside our assessment of the wider evidence base. Together, they provide a clear pathway to tackling the challenges identified and supporting the objectives of the UK Government's Modern Industrial Strategy.

2 Introduction

2.1 The UK's Modern Industrial Strategy

In June 2025, the UK Government set out its Modern Industrial Strategy, a ten-year plan designed to boost business investment and accelerate the growth of future-facing industries in the UK (Department of Business and Trade, 2025). Central to this strategy is the identification of eight priority sectors (the IS-8) with the highest future growth potential. One of the IS-8 sectors identified was Digital and Technologies, which contains six frontier industries:

- Advanced connectivity technologies (ACT)
- Artificial intelligence (AI)
- Cyber security
- Engineering biology
- Quantum technologies
- Semiconductors

While these are industries in their own right, it is clear from the Industrial Strategy that they also significantly overlap with and act as key enablers for the other IS-8 sectors.

2.2 The importance of skills in the Modern Industrial Strategy

A key theme arising from the Industrial Strategy consultation responses was the value of enhancing skills and accelerating access to talent across the IS-8 sectors (DBTa, 2025). While the UK has strengths in this area, skills shortages and skills development were identified as fundamental potential barriers in these industries. The consultation notes that currently, only 9% of secondary-level vocational learners are enrolled in the in-demand fields of engineering, manufacturing, and construction, compared with an OECD average of 32% (DBTa, 2025). At the higher education level, university applications for engineering and technology courses have increased by 20% over the past five years, yet the number of engineering graduates entering the labour market has remained broadly unchanged (DBTa, 2025), indicating that supply is not keeping pace with industry demand. Businesses across the IS-8 industries reported that the UK's education and training system lacks the flexibility and responsiveness needed to meet evolving skills needs, particularly in equipping workers with integrated technical, digital, and managerial competencies.

For the Digital and Technologies sector in particular, Lloyds Bank found that in 2024, around 7.3 million working-age adults lack the essential digital competencies needed in the workplace, making basic digital skills the UK's largest anticipated skills gap by 2030 (Lloyds Bank, 2024). Alongside this challenge for the existing workforce, Skills England's engagement with industry highlighted acute shortfalls in recruitment in advanced areas such as machine-learning, user experience design, biomedical applications, and big data (DfE,

2025). A UK government research briefing notes that almost half of engineering and technology firms face difficulties with recruitment due to skills shortages (Greaves et al, 2025). This was echoed by the Institution of Engineering and Technology (IET, 2021), which reported an estimated shortfall of over 173,000 workers across the UK STEM workforce, with associated STEM skills gaps estimated to cost the economy around £1.5 billion each year.

This is echoed by a Royal Society (2025) report, which highlighted that the UK risks persistent STEM skills shortfalls, driven in part by a shortage of specialist teachers to train the next generation of research and development (R&D) talent. International competition for expertise, constrained and uneven funding, and students' concerns about debt also make PhD recruitment harder, weakening the pipeline of skilled researchers. These gaps in STEM skills likely hinder productivity and economic growth, and threaten progress on wider policy priorities such as net zero and energy security. The Royal Society (2025) report also notes that the shortage of technical skills reduces the UK's appeal to inward investors and constrains businesses' capacity to capitalise on new ideas. The same report outlined how intermediate technical skills play a crucial role in strengthening organisations' absorptive capacity, enhancing their ability to recognise, interpret, and implement new ideas and innovations.

With Skills England's (2025) assessment of priority technologies indicating that Digital and Technologies will be one of the IS-8 sectors facing the largest increases in employment demand between 2025 and 2030, the current challenges with skills and recruitment are expected to grow.

2.3 Understanding the technical skills landscape in frontier industries

Given the critical role the Digital and Technologies sector and its six constituent frontier industries play in the Modern Industrial Strategy, it is essential for the UK Government to understand the technical skills landscape in each of these industries so that barriers can be addressed.

The UK Institute for Technical Skills & Strategy (UK ITSS) has therefore commissioned Frontier Economics to assess the technical skills landscape for each of the six frontier industries. The primary objective of this study is to assess the current state of technical skills in each frontier industry, and how demand for technical roles may change in future. Specifically:

- The economic contribution of each frontier industry;
- The demographic profile of employment within each frontier industry; and
- The current landscape of technical skills, and how this is expected to change in future.

The role of universities, research institutes, and policymakers in helping address any gaps identified in the technical skills landscape are also explored as secondary objectives.

2.4 Defining a technical professional

To examine the technical skills landscape, it is necessary to clarify what is meant by a technical professional (also known as a "technician"). As noted by the TALENT Commission (2025), there is no universally agreed definition. For instance, existing definitions include:

- **The Technician Council (2011)**: "A person who is skilled in the use of particular techniques and procedures to solve practical problems, often in ways that require considerable ingenuity and creativity. Technicians [technical professionals] typically work with complex instruments and equipment, and require specialised training, as well as considerable practical experience, in order to do their job effectively."
- **HEaTED (2018):** "A person who is trained and/or skilled in the techniques, tools and technology of their subject, who provides the practical application of knowledge, including hands-on support in directly contributing to teaching and learning, research and enterprise activities."
- **Research Councils UK (2020): "**Technology/skills specialists maintain and develop new and improved approaches to implement technologies and methodologies to better address research questions. Technology/skills specialists have specialist knowledge and expertise, and they often work as part of coordinated teams spanning different disciplines and geographical centres, which work together to tackle contemporary research questions. May include, but not limited to: data scientists, data engineers, archivists, informaticians, statisticians, software developers, audio-visual technologists, technical professional staff, and individuals staffing core facilities across all disciplines."
- **UKRI (2021):** "Technicians [technical professionals] typically use their technical expertise and knowledge and their practical, analytical and management skills to make a range of vital contributions to research and innovation, including (but not limited to): Delivering the goals of a research and innovation project; Maintaining and developing the environment, standards, resources, materials and facilities needed to deliver research and innovation; Teaching others in the design, use and analysis of research techniques and methodologies; Managing budgets, procurement and teams directly associated with research projects, equipment, instruments and research resources."

Although terminology varies, all definitions emphasise the practical application of knowledge, skills and expertise as central to technical roles. This highlights the breadth and diversity of occupations within the technical workforce. Accordingly, this report does not adopt a single definition or classification, as doing so could risk excluding certain roles. Instead, we take a broad interpretation of the term "technical professional" and apply it across the frontier industries, recognising that what constitutes a technical professional can differ significantly between industries.

2.5 Report structure

To address the objectives above, this study was divided into two parts.

- **Part One:** Synthesises existing evidence and data sources through a rapid evidence assessment.
- **Part Two:** Builds on the findings from Part One through a programme of qualitative engagement with technical professionals, universities, research institutes, and industry bodies across each frontier industry.

This report contains the synthesised findings across parts one and two, and is structured as follows:

- **Methodological approach:** Outlines the methodology in both Part One and Part Two of this study.
- **Economic contribution of frontier industries:** Presents evidence on their scale, economic contribution and workforce size.
- **Demographic profile of employment:** Examines the demographic composition of roles within each industry, including education, gender, ethnicity, and age where data is available.
- **Current technical skills landscape:** Reviews existing evidence on skills gaps and workforce shortages across frontier industries.
- **Future shortfall of technical professionals:** Presents modelled estimates of the cumulative future shortfall in technical roles across each industry from 2025 to 2035.
- **Role of universities and research institutes:** Summarises evidence on how universities and research institutes contribute to addressing identified skills gaps.
- **Conclusion:** Summarises the findings from the study.

3 Methodological approach

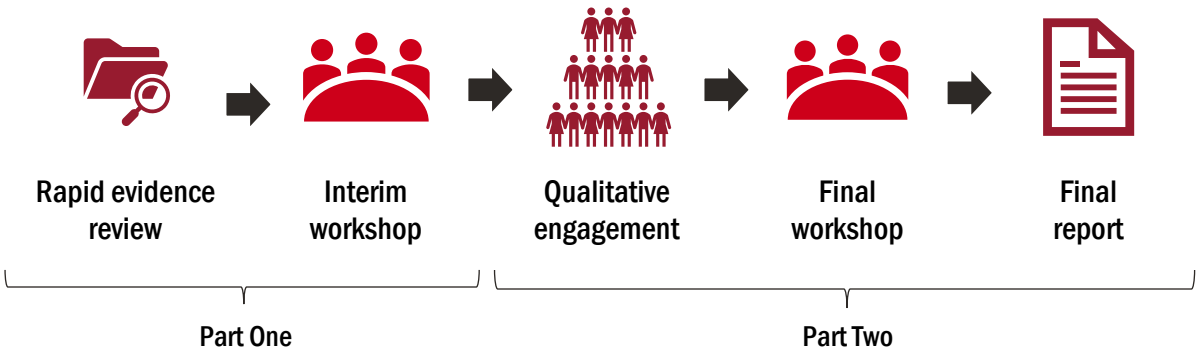
This chapter sets out the methodological approach for this study. We carried out:

- Part One: A rapid evidence assessment; and
- Part Two: Qualitative engagement with stakeholders.

3.1 Overarching design

Figure 8 outlines the overarching methodological design of the study. It explains how parts one and two are linked and the engagement that took place at each stage.

Figure 8 Methodological approach



Source: Frontier Economics

Part One of the study began with a rapid evidence assessment. This aimed to identify what is currently known about the technical skills landscape in each frontier industry, how this might change in future, and the role of universities and research institutes. Projections were developed to estimate the cumulative shortfall in technical professionals across each industry over the period 2025 to 2035. A gap analysis was then conducted, highlighting where evidence is of poorer quality or missing.

After the rapid evidence assessment was concluded, an interim workshop with policy-focused stakeholders from UK Government departments and research institutes was then conducted. The purpose of the workshop was fourfold:

- **Findings:** Ensure we have covered all available key evidence;
- **Methodology:** Test our approach to forecasting shortfalls in technical professionals;
- **Gaps:** Prioritise the gaps identified, focusing on those of highest importance to policymakers; and
- **Qualitative engagement:** Identify and agree on the set of stakeholders to interview for Part Two of the study.

Reflecting this feedback, we moved into Part Two of the study. Three successive rounds of qualitative engagement were then completed:

- Small group interviews with technical professionals;
- One-on-one interviews with industry leaders; and
- A roundtable discussion with industry bodies, universities, and research institutes.

The aim of this engagement was to fill, where possible, the prioritised set of gaps from the interim workshop. Insights from the literature review and qualitative engagement were then triangulated, with the remaining gaps clearly identified for further investigation. This informed a set of initial policy recommendations, which aimed to address the key gaps and barriers identified.

After the qualitative engagement was completed, a final workshop with the same set of policy-focused stakeholders from the interim workshop was conducted. The purpose of this workshop was twofold:

- **Findings:** Test the final findings from the evidence review, interviews, and roundtable discussion; and
- **Policy recommendations**: Test our initial policy recommendations.

Feedback received at the final workshop helped to refine the policy recommendations.

The following sections describe in detail the specific search methodology, definitions, and approach to qualitative engagement this study applied.

3.2 Part One: Rapid evidence assessment

Part One of this study applied a rapid evidence assessment approach to systematically identify, review, and synthesise existing evidence on the technical skills landscape across the six frontier industries within the Digital and Technologies sector. It examined evidence on five areas: the economic contribution of these industries, the demographic characteristics of their workforce, the current technical skills landscape, future technical skills needs, and the role of universities and research institutes in supporting them. A gap analysis was also conducted, highlighting where evidence is of poorer quality or missing.

3.2.1 Methodology

A rapid evidence assessment was conducted between July and October 2025, covering academic, government, and grey literature sources. Targeted searches were made in databases such as Google Scholar and official repositories such as:

- The Department for Science, Innovation and Technology (DSIT);
- The Department for Business and Trade (DBT) (formerly known as the Department for Business, Energy and Industrial Strategy (BEIS));

- The Department for Education (DfE);
- Skills England;
- UK Research and Innovation (UKRI);
- The Organisation for Economic Co-operation and Development (OECD);
- RAND;
- The House of Lords; and
- The House of Commons.

Each search combined industry-specific and thematic keywords (for example, “AI technical skills shortage UK”, “quantum workforce UK demographics”, “semiconductor technician pipeline”, “cyber security workforce diversity statistics”).

Documents were screened for relevance against three inclusion criteria:

- **Scope:** Evidence must concern one or more of the six frontier industries or cross-cutting issues within the Digital and Technologies sector.
- **Focus:** Evidence must address at least one of the four themes: (i) the economic contribution of these industries, (ii) the demographic characteristics of their workforce, (iii) current and future technical skills needs, and/or (iv) the role of universities and research institutes in supporting them.
- **Recency and reliability:** Preference was given to UK Government publications (especially recent DSIT studies from 2023 to 2025) and credible industry reports published since 2020.

Over 100 evidence sources were initially identified, of which approximately 80 met the inclusion criteria and were retained for in-depth review. The evidence base was then categorised by industry and mapped against the four analytical themes.

Each source was assessed for:

- Quality and rigour (methodological transparency, data robustness);
- Relevance to the UK context;
- Breadth and depth of coverage across skills, workforce, and education themes.

Findings were triangulated across sources to produce a consistent cross-industry assessment and to identify evidence gaps requiring further exploration through the forthcoming workshop and qualitative interviews with stakeholders from industry, universities, and research institutes.

3.2.2 Definitions of the frontier industries

To assess the current state of technical skills in each frontier industry within the Digital and Technologies sector, and how demand for technical professionals may evolve, it is first

necessary to define each of the six frontier industries. DBT (2025b) defines each of them at a high level as follows:

- **Advanced connectivity technologies (ACT):** Companies undertaking work in a range of cutting-edge technologies that enable the transmission of data in our increasingly digitised economy and society, connecting people and things. These include technologies that make up advanced wireless systems, such as 5G and the transition to 6G, non-terrestrial networks, advanced optical networks, the integration of AI – and, in time, quantum – with communications. ACT was previously referred to as "future telecoms" (DSIT, 2025).
- **Artificial intelligence (AI):** Companies that provide AI services, products, and infrastructure.
- **Cyber security:** Companies that protect the technology we rely on for everyday life and work. This includes protecting critical infrastructure like power grids, securing personal data in healthcare systems, and safeguarding financial institutions from fraud.
- **Engineering biology:** Companies that engage in the design, scaling, and commercialisation of biology-derived products and services that can transform sectors or produce existing products more sustainably.
- **Quantum technologies:** Companies and innovators that develop and sell products and services based on quantum phenomena, or whose principal applications are in quantum technologies.
- **Semiconductors:** Companies engaging in semiconductor design, development, and manufacturing.

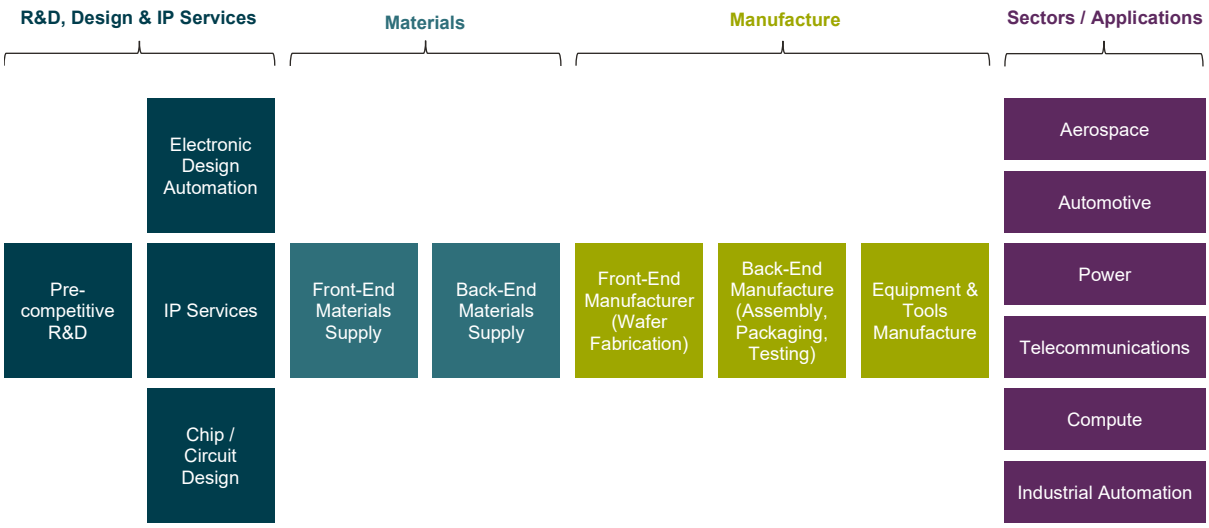
To identify specific businesses within each industry, Standard Industrial Classification (SIC) codes are often used. These codes classify, using a standardised system, the main activities businesses undertake. A challenge with identifying businesses within these industries is that all six do not have specific SIC codes clearly identifying businesses undertaking these activities. This makes it difficult to accurately and consistently measure economic activity in these industries. A similar challenge is faced for measuring the size of the workforce, as Standard Occupational Classification (SOC) codes (the workforce equivalent of SIC codes) also do not easily map to roles in these industries.

With this in mind, the UK Government has published several separate studies covering all six frontier industries. In these studies, they attempt to identify businesses and jobs in these industries using SIC and/or SOC codes which are broadly adjacent to the activities undertaken in these industries. To identify these codes, a business-focused taxonomy is often used.

Figure 9 below provides an example for semiconductors. DSIT's (2024) semiconductor sector study outlines the supply chain of the industry, mapping the diverse activities that make up the semiconductor supply chain. This enables companies to be grouped by their "best fit" segment, while recognising that many firms operate across multiple parts of the chain (for example, undertaking both design and manufacturing).

Using these taxonomies, sector studies are then able to provide an indication of the size (in terms of revenue and the number of firms) and economic contribution (measured through gross value added, GVA) of each frontier industry. These are presented in Chapter 4.

Figure 9 Semiconductors taxonomy



Source: Adapted from DSIT (2024), Semiconductor sector study

3.2.3 Scale of evidence

Table 2 summarises the scale of evidence across each of the six frontier industries from the rapid evidence assessment, showing how they compare to one another. More detailed analysis for each industry is presented in the following chapters.

Table 2 Relative scale of evidence across frontier industries

Frontier Industry	Scale of Evidence	Overview of Evidence
ACT	Lower	While industry-wide evidence exists for telecoms and broadband infrastructure, few studies isolate ACT as a distinct industry. The DSIT Connectivity Sector Study (2024) provides baseline data on economic contribution and employment but limited detail on workforce composition, skills needs, or technical professional roles. Evidence on university and industry training pathways is minimal.
AI	Higher	Stronger evidence base, including DSIT sector studies (2022 to 2025), academic analyses, and industry surveys. Relatively more robust data on economic contribution, workforce size, demographics, and skills shortages. Limited evidence on the role or proportion of technical roles specifically. Most evidence concerns AI deployment skill gaps (programming, systems engineering, data analysis), with fewer studies on covering gaps in AI systems development. Less evidence on the role of universities.
Cyber security	Higher	Comprehensive DSIT sector analysis (2025) provides detailed quantitative data on firm demographics, workforce size, and diversity. Well-evidenced annual workforce gap and rich qualitative analysis of recruitment barriers and skill shortages. Evidence stronger on further education (FE) and higher education (HE) pathways and diversity barriers, but weaker on technical roles and cross-industry integration.
Engineering biology	Lower	Limited evidence. DSIT (2025) provide information on economic contribution and workforce size. Some descriptive material on applications and investment, but little on workforce composition, skills needs, or technical roles. Current studies focus mainly on R&D and innovation potential rather than labour market implications.

Frontier Industry	Scale of Evidence	Overview of Evidence
Quantum technologies	Medium	Increasingly detailed evidence since 2023 through DSIT, UKRI, and Quantum Skills Taskforce outputs. Good coverage of economic contribution, total employment, workforce characteristics, education pipeline, and gender diversity, but limited data on technical roles and replacement needs.
Semiconductors	Higher	Stronger evidence base, with the DSIT Semiconductor Workforce Study (2024) providing data on economic contribution, employment, skill shortages, replacement needs, and education alignment. Stronger evidence base for technical roles and workforce ageing. Evidence is less strong on diversity and vocational entry routes, but quantitatively the most complete of all frontier industries.

Source: Frontier Economics

3.3 Part Two: Qualitative engagement

Part Two of this study gathered qualitative evidence from universities, research institutes, industry bodies, industry leaders, and technical professionals across each frontier industry to address the identified evidence gaps and validate the findings from the rapid evidence assessment. In particular, this part of the study sought to enrich the existing evidence with qualitative insights on three primary areas that were prioritised at the interim workshop:

- The current skills landscape;
- Future technical skills needs; and
- The role of universities and research institutes in supporting them.

The qualitative engagement was also designed to explore the causes of the challenges faced by the industries, as well as identifying potential solutions.

To ensure the findings were as robust as possible, three successive rounds of qualitative engagement were completed, each with a different purpose:

- **Group interviews with technical professionals:** Six group interviews were held - one for each frontier industry - to ensure views from all industries were heard. Between 1-4 technical professionals were included in each interview. The purpose of the interviews

was to hear directly from technical professionals about the technical skills currently needed (and possibly experiencing shortages) in their industry, how those technical skills needs may change in future, and any barriers they face working in and entering technical roles in their industry. Invitations were shared with technical professionals within UK ITSS's network of contacts, covering roles predominantly (but not exclusively) within universities and research institutes.

- **One-on-one interviews with industry leaders:** Interviews were then held with industry leaders representing the different frontier industries. Invitees predominantly included members of industry-specific UK Government advisory panels, and were contacted directly by Frontier Economics. Their purpose was to explore the same themes as the small group interviews, whilst gaining a higher-level perspective from those with a broader view of the industry.
- **Roundtable discussion with industry bodies, universities and research institutes:** Finally, a roundtable discussion was held with individuals at industry bodies, universities, and research institutes from across the frontier industries. The purpose of the discussion was to validate the findings from the interviews, as well as exploring (i) the causes of the current technical skills shortages faced by frontier industries, and (ii) potential solutions that could address the current and forecast technical skills shortages in the frontier industries. Invitations were shared with participants based on UK ITSS's network of contacts as well as Frontier Economics' own outreach to stakeholders at relevant industry bodies.

An interview guide was developed and applied to ensure consistency in approach across the interviews with each frontier industry.

As shown by Figure 10, the qualitative engagement was designed to ensure a plurality of views were heard. In particular, the qualitative evidence covers:

- **31 stakeholders in total:** The qualitative engagement included six small group interviews with 1-4 participants (15 stakeholders in total), interviews with two industry leads, and a roundtable discussion with 14 participants.
- **Representatives from all six frontier industries:** Small group interviews were conducted for each frontier industry, with the roundtable discussion also including at least one representative from each. Two industry leaders were interviewed, representing the ACT and engineering biology industries respectively.[6]
- **A range of perspectives:** By engaging technical professionals, industry leaders, industry bodies, universities, and research institutes, the qualitative evidence covers a broad range of perspectives.

[6] Industry leaders from the remaining four industries were not available to be interviewed within the timeframe of this study.

Figure 10 Summary of qualitative engagement

Source: Frontier Economics

4 Economic contribution of frontier industries

This chapter sets out the available evidence on the number of firms operating within each frontier industry, how many people they employ, and their overall contribution to the wider economy. By providing a basis for understanding their relative size, this chapter provides the foundation for an assessment of the types of technical skills required in each industry and their likely future growth trajectories.

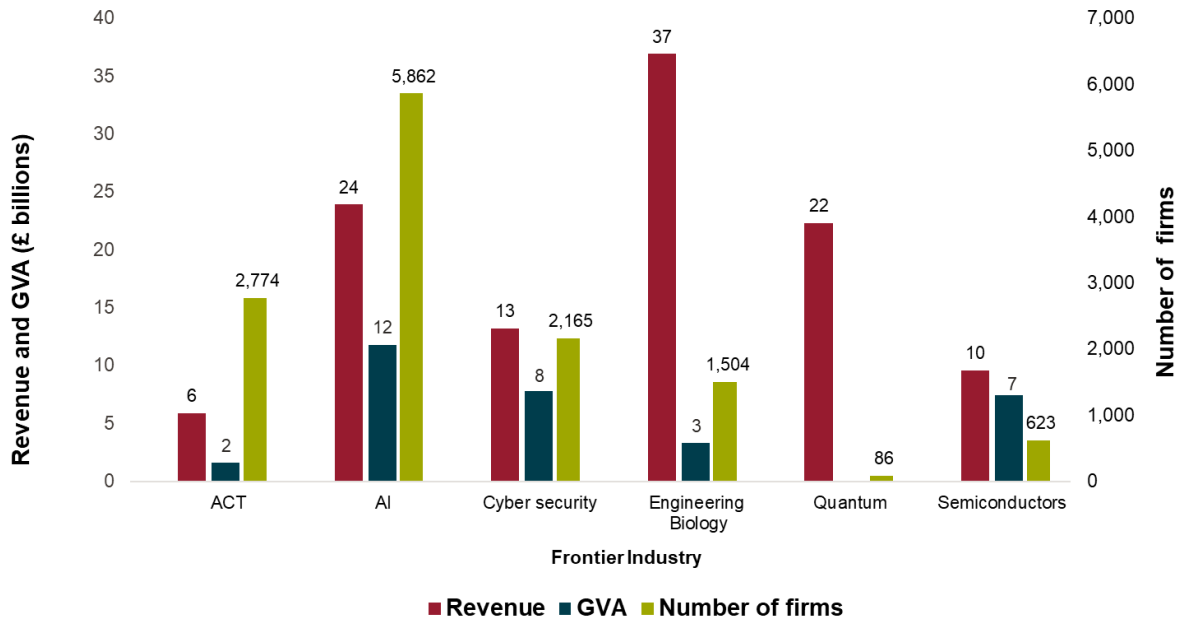
Reflecting the feedback from the interim workshop, economic contribution was not prioritised as a key topic for the qualitative engagement. Therefore, this chapter focuses on the findings and policy recommendations arising from the rapid evidence assessment only.

4.1 Estimates of revenue, GVA and number of firms in each frontier industry

Figure 11 summarises estimates of revenue, GVA and number of firms operating in each frontier industry, taken from a range of different DSIT studies. It shows the high degree of variation in the size of the different frontier industries; the largest being engineering biology with revenues of nearly £37bn in 2022-23, and the smallest being ACT with revenues of £5.9bn in 2024.

The wide range of estimates may partly reflect challenges in measuring the size of each industry. For example, alternative sources like The Data City (2025) cite a revenue figure for the quantum technology sector of £59.1bn - more than double the DSIT (2025) figure of £22.3bn. This highlights the challenges of accurately classifying and measuring the size and economic contribution of some of these industries, making it an important potential area for official statistics to develop in future.

Figure 11 Estimates of the size and economic contribution of each frontier industry



Source: *DSIT (2025) ACT Market Scoping Analysis 2025, DSIT (2025) Artificial Intelligence sector study 2024, DSIT (2025) Cyber security sectoral analysis, DSIT (2025) Engineering Biology, Quantum Technology and Robotics and Autonomous Systems analysis, and DSIT (2024) Semiconductor sector study.*

Note: *ACT data is for 2024 (apart from the number of firms, which is for 2025); AI is for 2024; cyber security is for FY2024/25; semiconductors is for 2022; and engineering biology and quantum technologies for 2022/23. Estimates are not directly comparable across industries, as figures are derived from different data sources and methodologies. The figures reported for ACT reflect the contribution of core ACT firms only (i.e. excluding hybrid firms). GVA estimates are not available for quantum technologies.*

Despite these measurement challenges, estimates collectively demonstrate the substantial economic contribution of the UK's frontier industries, reflecting both their current scale and their potential to drive growth. For example:

- **ACT:** Generated an estimated £1.6 billion in GVA in 2024, driven by the continued rollout of 5G and investment in 6G and optical networks (DSIT, 2025a).
- **AI:** Between 2023 and 2024, the industry's GVA in the UK doubled, revenue increased by 68%, and the number of firms grew by 58% (DSIT, 2025c).
- **Cyber security:** The industry recorded £13.2 billion in annual revenue, increasing 12% year-on-year, and £7.8 billion in GVA - a 21% increase (DSIT, 2025d).
- **Engineering biology:** Evidence remains less developed, but global estimates suggest it could deliver between $2 to 4 trillion in annual impact over the next two decades (McKinsey, 2020).
- **Quantum technology:** Though smaller than the other industries, in 2021/22 it accounted for around 9% of the global market and 12% of global private investment (DSIT, 2023a). Oxford Economics estimate that by 2045 it could boost UK productivity

by up to 8%, equivalent to a potential increase of up to £212 billion in the UK's GDP (Oxford Economics, 2025).

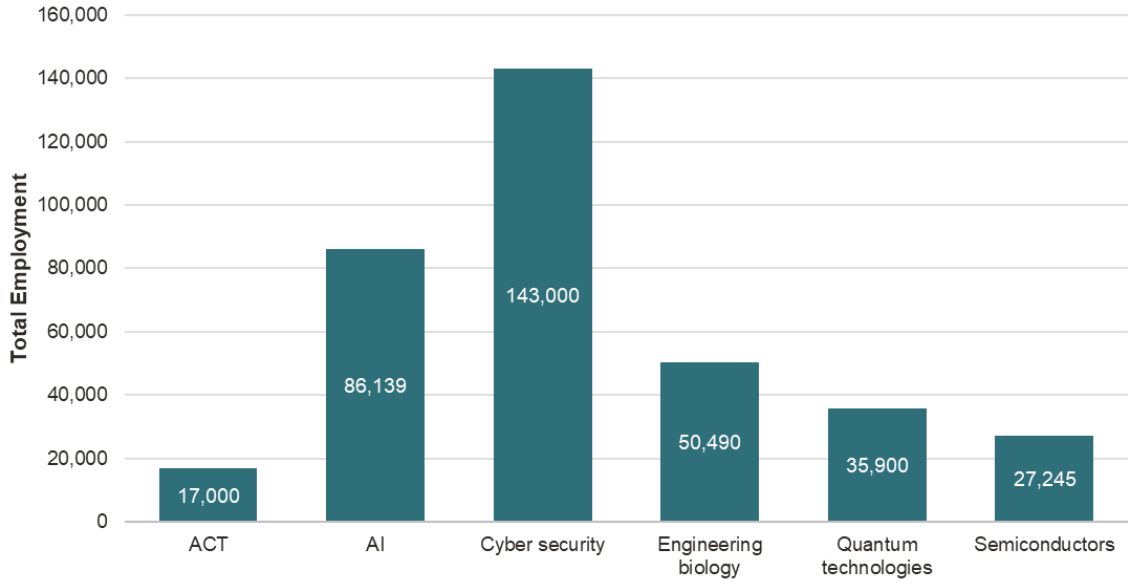
- **Semiconductors:** this industry is highly productive, with GVA per employee averaging £460,000 (DSIT, 2024).

4.2 Employment in frontier industries

To estimate the current and future gap in technical skills, employment estimates for each industry are required. DSIT's sectoral studies provide aggregate workforce estimates, rather than for technical professionals specifically. These are presented Figure 12. The exception to this is the semiconductor industry, where DSIT also estimate the share of workers in technical roles (69%). Overall, it is clear, as with revenue, number of firms and GVA contribution, that the sizes of the frontier industries vary considerably.

As noted earlier in relation to industry revenue, differences in methodology between The Data City and DSIT produce markedly different employment estimates. For instance, The Data City (2025) estimates employment in the AI industry at 380,525, whereas DSIT (2025a) reports a figure of 86,139. Across the industries where both sources provide data (AI, cyber security, engineering biology, quantum and semiconductors), The Data City's employment estimates are, on average, around 4.6 times higher than those reported by DSIT.

Figure 12 Employment in frontier industries



Source: *DSIT (2025) ACT Market Scoping Analysis 2025, DSIT (2025) Artificial Intelligence sector study 2024, DSIT (2025) Cyber security sectoral analysis, DSIT (2025) Engineering Biology, Quantum Technology and Robotics and Autonomous Systems analysis, and DSIT (2024) Semiconductor Workforce Study.*

Note: *ACT and AI data are for 2024, cyber security is for FY2024/25, semiconductors is for 2025, and engineering biology and quantum technologies for 2022/23. Employment estimates are not directly comparable across industries, as figures are derived from different data sources and methodologies.*

4.3 Summary of findings and identified gaps

The evidence base on the economic contribution of the frontier industries remains uneven, limiting the ability to compare their scale and assess their economic impact. There is rarely data disaggregated below the national level. In particular, we find:

- The six frontier industries vary significantly in their size and economic contribution. Engineering biology and AI represent the largest industries by revenue, followed by quantum technologies and cyber security, while semiconductors and ACT remain smaller. In terms of GVA, AI and cyber security are the largest, followed by semiconductors, engineering biology and ACT.
- A common theme across the frontier industries is how the reported figures for revenue, GVA and employment vary substantially across sources. This reflects uncertainty over industry definitions and the use of differing methodologies and taxonomies. Furthermore, sector studies use varying survey frames, modelling assumptions, and time periods, reducing comparability across industries.

4.4 Policy recommendations

Based on the findings set out above, we make three policy recommendations relating to the economic contribution (EC) of frontier industries (EC1 to EC3):

EC1 Standardise, where possible, the approach to data collection, modelling assumptions, taxonomies, and timeframes across studies. This could include developing new or adapted SIC and SOC classifications (or potentially hybrid options). This will minimise ambiguity and enable more accurate comparisons across industries.

EC2 Gather data to provide detailed breakdowns of the number of technical roles and their type in each industry. This would enable more detailed analysis of skills needs in these industries.

EC3 Provide a regional breakdown of economic statistics (revenue, number of firms, GVA, number of employees). This breakdown should be at the ITL1 level as a minimum, or in line with the Skills England's (2025a) specified areas in their Local Skills Improvement Plans.[7,8] This will help identify and track industry clusters as they develop over time.

[7] ITL1 refers to the highest level of major socioeconomic regional breakdown, consisting of nine English regions (like London, South East, etc.) plus Scotland, Wales, and Northern Ireland.

[8] Skills England identify 'specified areas' for local skills improvement within the North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East, Greater London, South East and South West. For example, Cheshire and Warrington, Cumbria, Greater Manchester, Lancashire and the Liverpool City Region are specified areas in the North West.

5 Demographic profile of employment in frontier industries

This chapter provides an overview of the demographic composition of the workforce across the six frontier industries, combining the findings from the rapid evidence assessment and the qualitative engagement.

The most comprehensive and comparable source across industries is the Jobs and Skills Dashboard (2024), which, drawing on expert input from DSIT policy leads, identifies the occupations most relevant to supporting each frontier industry.[9] The dashboard provides data on gender balance, projected employment growth, vacancies, and educational pathways for these roles. The estimates cover all relevant occupations, rather than focusing solely on technical roles.

The estimates for each role are, however, economy-wide, rather than specific to those employed within each frontier industry. Nevertheless, the dashboard offers valuable quantitative insights into the educational pathways and demographic profiles associated with all roles (including technical) that underpin each industry.

Where possible, we have supplemented these estimates with evidence from sector studies, government reports, industry literature, and the insights from the qualitative engagement. These additional sources help to contextualise the demographic data, highlighting variations in educational background, diversity, and inclusion across the technical workforce.

5.1 Educational pathways for technical professionals

To estimate the educational pathways of early-career workers (defined as 23- to 30-year-olds) relevant to the frontier industries, the Jobs and Skills Dashboard (2024) uses data from the Annual Survey of Hours and Earning (ASHE) and Longitudinal Education Outcomes (LEO) studies for 2019. Table 3 below presents this information across the frontier industries.

Frontier industries predominantly rely on roles where workers participated in higher education, with the percentage of early-career workers completing their education with this pathway standing above 63%. Furthermore, the table shows that the majority of individuals in these roles studied a Science, Technology, Engineering, and Mathematics (STEM) subject. Similar themes emerged throughout the qualitative engagement, where interviewees highlighted that the primary pathway into the industries is through higher education, with STEM subjects being the most common degree backgrounds. Universities and STEM

[9] The dashboard does not contain a dedicated cyber security occupational category, so data for digital and computing occupations have been used as a proxy.

subjects are therefore likely to play a central role in filling the technical skills gaps identified. This is discussed further in Chapter FS1.

5.2 Gender diversity challenges in frontier industries

The Jobs and Skills Dashboard (2024) provides an insight into the percentage of roles held by women for each role, based on the Annual Population Survey (APS) for the period 2022 to 2023. Taking an average across these roles, Table 3 reveals that, across all of the frontier industries, the vast majority of roles identified by DSIT as relevant were held by men. This is consistent across industries, with the percentage of female workers ranging between 19% and 22%. Understanding what drives this large disparity is central to opening up the roles supporting these industries to a wider demographic.

Table 3 Demographic composition of roles identified as relevant to the frontier industries

Frontier industry	Early-career workers entering via higher education (%)	Early-career workers completing a STEM subject (%)	Female (%)
ACT*	63%	60%	20%
AI	72%	61%	22%
Cyber security**	64%	55%	22%
Engineering biology	63%	71%	22%
Quantum technologies	67%	73%	19%
Semiconductors	63%	71%	22%

Source: *Jobs and Skills Dashboard (2024)*

Note: *ACT data corresponds to "Future Telecommunications" in the Jobs and Skills Dashboard. "Digital and Computing" is used as a proxy for cyber security.*

Gender diversity was raised repeatedly in the qualitative engagement across all six frontier industries, with a large number of participants highlighting it as a significant issue. This was raised for both technical professionals and founders of startup companies. Although stakeholders struggled to identify industry-specific causes for diversity issues, broader challenges were raised regarding (i) women transitioning away from the workforce due to childcare responsibilities, (ii) low female participation in STEM subjects, (iii) poorer career progression opportunities for women, and (iv) gender biases in funding opportunities.

Throughout the qualitative engagement, participants offered possible solutions for tackling diversity challenges. In particular, they mentioned the importance of building interest in technical roles at a young age (i.e. GCSE level or before) in order to attract both male and

female students, after which it becomes too late to tackle gender imbalances. Possible interventions suggested by stakeholders included:

- Supporting widespread work experience opportunities to improve awareness of and interest in the roles and opportunities available across the frontier industries;
- Implementing more inclusive language when engaging younger generations;
- Showcasing successful industry role models from a variety of backgrounds to break down reputational challenges around the industries being male-dominated; and
- Increasing structural support through scholarships or funded programmes that aim to tackle diversity issues.

Stakeholders cited programmes such as the Aspire Award Undergraduate Scholarship by UCL (a computer science programme creating opportunities for students from Black or mixed Black ethnic backgrounds) and the Daphne Jackson Fellowship (a fellowship opportunity aimed at individuals who have had to take a break from work for family, caring or health reasons) as good examples of structural support programmes that help to break down diversity challenges in industry.

5.3 Industry-specific evidence

In this section, we perform a deep-dive into the demographic composition of each industry, drawing in additional evidence beyond the Jobs and Skills Dashboard and from the qualitative engagement where available.

5.3.1 Advanced connectivity technologies

As shown above, data from the Jobs and Skills Dashboard (2024) reveals that 63% of early-career entrants into the ACT[10] industry come through higher education pathways, with 60% having studied a STEM subject. In addition, women made up just 20% of the workforce in 2022/23, closely aligning with figures across the wider telecommunications industry, where women represent less than one fifth (20%) of the UK workforce. This sits significantly below the global telecommunications industry average of 37% (Dobson, 2025). Beyond the Jobs and Skills Dashboard, there is limited detailed demographic data available on the ACT workforce.

However, DSIT does provide estimates on demographic composition in the wider UK telecommunications workforce as part of its data on the economic estimates for the Digital Sector (DSIT, 2025g). The 2024/25 data indicates that men accounted for roughly 70% of the workforce, with women representing 30%. The age profile is also skewed towards mid- and late-career workers. In particular, around 29% were aged 35-44, 25% were aged 45–54, and 18% were aged 55–64, with only about 10% of workers under 25. Furthermore, the

[10] The Jobs and Skills Dashboard classifies this industry under “Future Telecommunications”, which is the previous terminology used to define advanced connectivity technologies (ACT).

industry remains predominantly White (83%), with around 6% identifying as Asian or Asian-British, 6% as Black, African or Caribbean, and 3% from mixed or other ethnic groups. The data also reveals that the workforce is also highly qualified, with around 53% holding a degree or equivalent or higher education qualification. Overall, this data indicates that the UK telecommunications workforce remains relatively homogeneous, being dominated by older, highly educated men.

Similar themes emerged from the qualitative engagement. For instance, interviewees confirmed that technical professionals often come from higher education backgrounds, typically with degrees in STEM subjects such as computer science or electronics. In addition, stakeholders described gender diversity challenges in the industry, as well as an ageing population due to difficulties in attracting younger technical professionals. Stakeholders suggested that the challenges driving diversity issues and an ageing population may arise as a result of a lack of awareness amongst younger generations around the types of roles that are available in the industry.

5.3.2 Artificial intelligence

Employment in AI-related roles has expanded significantly in recent years. DSIT's latest AI sector study estimates that around 86,000 people were employed in AI roles in 2025, compared with just over 50,000 in 2022, which is an increase of more than 70% in only three years (DSIT, 2025c). This rapid expansion is underpinned by a highly educated workforce, with nearly three quarters of early-career entrants coming through higher education (compared with 40% across the economy), and more than 60% holding a STEM degree as their highest qualification - more than double the labour market average (Jobs and Skills Dashboard, 2024). OECD (2023) evidence confirms this picture, showing that, in the UK, two thirds of the AI workforce have a tertiary degree, rising above 75% in the most AI-intensive occupations such as software and application developers. These findings were also corroborated throughout the qualitative engagement, where interviewees confirmed that higher education is the primary pathway into the industry, with AI technical professionals emerging from a wide variety of degree backgrounds (interviewees primarily cited examples from STEM subjects, such as computer science, software engineering and genetics).

Despite this growth, the workforce continues to face persistent diversity challenges, particularly in relation to gender. As shown above, women make up only around 22% of AI and data science professionals in the UK (Alan Turing Institute, 2021). This is lower than both the overall UK workforce (48%) (Jobs and Skills Dashboard, 2024) and the global average for AI in 2021 (26%) (Alan Turing Institute, 2021). Where women are present, they are more likely to be concentrated in less technical sectors such as healthcare and under-represented in technical IT roles. In addition, research finds that women working in AI tend to hold higher formal qualifications than their male counterparts, particularly at senior levels, yet remain under-represented in leadership positions, including C-suite roles (Alan Turing Institute, 2021). The qualitative engagement validated the findings around the AI industry being heavily male-dominated. Whilst participants reported that the gender balance has

been improving in recent years, it was noted that this trend started from a particularly low starting point.

On age composition, OECD (2023) analysis shows that the UK AI workforce is not noticeably younger than other tertiary-educated workers. Around 44% of AI workers in the UK are under 40, compared with roughly 48% across the wider tertiary-educated workforce. This suggests that AI employment opportunities are not confined to younger cohorts, but rather spread across early-, mid- and late-career professionals. Although examples where ethnic minority groups are under-represented were raised at the roundtable discussion, analysis by the OECD (2023) suggests that the workforce is also internationally diverse, with the UK recording one of the highest proportions of foreign-born workers in AI across the OECD. Overall, the evidence points to the AI workforce being shaped by higher education and persistent gender imbalances.

5.3.3 Cyber security

Currently, the Jobs and Skills Dashboard (2024) does not contain dedicated data for the cyber security industry; instead, the broader category of digital and computing occupations is used as a proxy so that it can be compared with the other industries. DSIT's (2025e) report on cyber security skills in the UK labour market does, however, provide a more detailed and industry-specific picture of the cyber security workforce, including its size, educational profile, and diversity.

DSIT (2025j) estimate that around 67,300 full-time equivalent employees work in cyber security-related roles across approximately 2,165 companies in the UK. The workforce is highly educated, demonstrated by the fact that 80% of employers recruiting for core cyber roles require at least a bachelor's degree (or equivalent), and a further 7% prefer or require a postgraduate qualification such as a master's or PhD (DSIT, 2025e). This level of qualification is higher than the Jobs and Skills Dashboard proxy for the digital and computing workforce, where around 64% of early-career workers enter via higher education (DSIT, 2025e).

The qualitative engagement emphasised that the typical pathway into the cyber security industry is through higher education, with many technical professionals entering through undergraduate or postgraduate routes. In addition, the workforce comes from a wider variety of degree backgrounds rather than necessarily pursuing specialised cyber security or STEM routes, with interviewees reporting that technical professionals are able to learn the more specialised technical skills on the job.

Detailed diversity information exists across a range of dimensions for the cyber workforce, highlighting a number of challenges:

- **Women account for just 17% of the workforce** (DSIT, 2025e), far below the UK workforce average of 48% and lower than the 22% estimate in the Jobs and Skills Dashboard (2024).

- **Representation of people from ethnic minority backgrounds stands at 19%**, broadly in line with the overall UK workforce average of 15% (DSIT, 2025e)
- **Disabled people are under-represented**, making up 8% of the cyber workforce compared with 17% across the UK workforce. Neurodivergent individuals represent 16% of the cyber workforce, with comparable benchmark data lacking (DSIT, 2025e).
- **Diversity declines further in senior roles.** Women make up just 12% of senior roles, ethnic minorities make up 8% and disabled people account for 5%, compared to their higher shares in the workforce as a whole. This suggests barriers to progression remain significant (DSIT, 2025e).

The UK Cyber Security Council (2023) has pointed to a range of barriers that continue to limit gender diversity in the industry. A frequently cited issue is the perceived shortage of female applicants. While women accounted for only 12% of undergraduates and 17% of postgraduates in cyber security courses in 2023, problems have been identified in how recruitment is carried out. Recruitment agents note that many hiring managers lack awareness of unconscious bias and seldom apply practices such as blind recruitment or inclusive job design. In addition, job descriptions are often unrealistic or overly demanding, discouraging potential candidates, particularly women, from applying. This challenge is compounded by limited knowledge of the wider cyber security labour market and the variety of pathways into the profession. In particular, smaller firms, which make up the bulk of the industry, often lack dedicated HR functions to address these issues, making it harder to implement diversity measures. As a result, the UK Cyber Security Council (2023) conclude that the claim that there are too few female applicants often masks the role of unconsciously biased recruitment practices, which themselves act as a barrier and contribute to the continued under-representation of women in cyber security.

Taken together, the data indicates that the cyber security industry continues to face difficulties in building a diverse workforce. The challenge of improving diversity is especially acute at senior levels, where representation is consistently lower across all groups.

5.3.4 Engineering biology

There is currently no research beyond the Jobs and Skills Dashboard (2024) directly reporting the demographic composition of the engineering biology workforce in the UK. As outlined above, the Dashboard shows that roles relevant to the industry appear to have a highly educated profile. Among early-career workers, 63% entered the industry via higher education pathways, compared with a much smaller share through vocational or technical routes. These findings were corroborated throughout the qualitative engagement, where interviewees confirmed that the majority of new entrants enter the industry with an undergraduate degree, and it is also common for new technical professionals to enter with a master's degree or a PhD.

As shown above, the Dashboard also reveals that 22% of relevant roles are held by women, reflecting the wider under-representation of women across STEM fields. Comparable

evidence from adjacent industries to engineering biology reinforces these patterns. The BioIndustry Association (BIA) reports that only 17% of biotech CEOs were women in the UK in 2024 (BIA, 2025), highlighting persistent barriers to leadership progression in closely related industries. Broader UK diversity benchmarks also indicate low participation from Black employees (around 1.6% of the biotech workforce) and under-representation of women in technical and manufacturing roles (BIA, 2023). In particular, EngineeringUK indicate that women make up only 17% of the UK engineering and technology workforce, while minority ethnic groups and disabled people each account for 14% (EngineeringUK, 2025). All of these figures fall below the averages observed across the wider economy. This evidence suggests that engineering biology is likely to face similar structural diversity challenges to those found across the broader STEM and biotech labour markets.

Similar themes emerged throughout the qualitative engagement, where gender diversity was raised as a key issue in the engineering biology industry. This was reported as being the case amongst technical professionals, as well as founders of startup companies. The latter was highlighted as particularly relevant for the engineering biology industry, given that a relatively large proportion of firms are startups or SMEs. Interviewees felt that gender diversity has become worse as the industry has shifted away from its R&D-intensive phase and towards a more manufacturing-heavy stage.

5.3.5 Quantum technologies

Roles relevant to the quantum technologies workforce appear to be strongly STEM-oriented. For instance, nearly three quarters (73%) of early-career roles relevant to quantum studied a STEM subject as their highest qualification, well above the 28% average across the wider economy (Jobs and Skills Dashboard, 2024). This reflects the industry's reliance on advanced scientific and engineering expertise, often at postgraduate level. Stakeholders agreed that the most common pathway into the industry is through higher education and, in particular, specialised degree backgrounds in quantum physics.

Despite this strong skills base, the industry faces challenges around inclusion. For instance, only 19% of relevant roles are held by women, which is a lower share than in both AI and semiconductors (Jobs and Skills Dashboard, 2024). Evidence from a London School of Economics study on diversity in the quantum industry underscores the scale of this imbalance, showing that only one in 54 applicants for quantum roles is female, and around 79% of quantum companies have no women in senior leadership positions (Josten et al., 2023). Nearly two thirds of employees surveyed believed their organisations should do more to improve representation and inclusion (Josten et al., 2023). In addition, throughout the qualitative engagement, participants reported that the gender balance has been improving in recent years, but that this trend started from a particularly low base.

Further detailed demographic information on the current workforce remains limited. However, student data outlined in the UK Quantum Skills Taskforce provides some insight into the pipeline of future workers (DSIT, 2025k). Enrolments in quantum-titled degrees remain small but are rising, particularly at postgraduate level. In 2021/22, there were 105

postgraduate taught students, 75 research postgraduates, and just 15 undergraduates enrolled in such courses. The profile of these students differs markedly from science and engineering as a whole. Between 2019/20 and 2021/22, over four fifths (82%) of entrants to quantum courses were aged 21-24, compared with 23% for all science students. This skew towards younger postgraduates reflects the predominance of master's and PhD courses. The majority of entrants were male (76%), compared with 45% across all science subjects. This shows that the pipeline of quantum talent continues to be male-dominated. Just over half (51%) were UK-domiciled, a significantly lower proportion than in science overall (76%), potentially highlighting the international appeal of UK quantum programmes. Ethnic diversity among quantum students broadly matched science averages, with around three quarters identifying as White (74%).

Together, these patterns suggest an industry with a strong academic and international orientation but also one facing challenges around gender imbalance.

5.3.6 Semiconductors

Evidence suggests that educational attainment across the semiconductors industry is notably high, with over 80% of workers holding at least a degree. In addition, postgraduate qualifications are common, with 14% holding PhDs (DSIT, 2025l). This is higher than the estimates provided by the Jobs and Skills Dashboard (2024), which notes that 47% of early-career workers completed their education through a higher education pathway. In contrast, vocational routes are rare, with less than 1% having apprenticeships or foundation degrees as their highest qualification (DSIT, 2025l). This points to the industry's strong reliance on advanced higher education training.

These findings were echoed throughout the qualitative engagement, where interviewees confirmed that the primary pathway into the semiconductors industry is through higher education, with the majority of entrants having at least an undergraduate degree. Interviewees also highlighted that a relatively high proportion of technical professionals in the semiconductors industry have a PhD. This is because studying for a PhD is often the first opportunity students can gain access to cleanrooms, which equip them with the relevant practical skills to enter technical careers.

The semiconductor workforce is relatively young, with an average age of 41 compared with 42 across the UK workforce (DSIT, 2025l). Most employees are between 25 and 49 years old, with relatively few entrants under 24, reflecting the high level of education required. However, an ageing workforce is evident, as around 39% of workers (c.10,700 people) are expected to reach retirement age within the next 15 years - equivalent to more than 700 employees exiting annually (DSIT, 2025l). This creates a substantial challenge for succession planning and skills transfer. Roles in manufacturing, integrated circuit (IC) design, electronic design automation (EDA) development, and product management are expected to face the greatest replacement needs, with between 13% and 30% of the current workforce projected to retire by 2040 (DSIT, 2025l).

The industry also faces persistent diversity gaps. Women make up just over a quarter of the total workforce (similar to the Jobs and Skills dashboard estimate of 22%), but only 18% of technical roles, compared with 45% of non-technical posts (DSIT, 2025l). Female representation at leadership level is even lower, with just over one in ten directors being women. Stakeholders agreed that the industry is male-dominated, and that low female participation rates impose a significant restriction on the supply of prospective technical professionals entering the industry. Although the industry has not yet achieved an equal gender balance, participants reported that this has been improving in recent years.

Data on nationality shows about 71% of workers are UK nationals, while 9% come from elsewhere in Europe and around 20% from other international locations (DSIT, 2025l). India, China, the United States, Nigeria, and Germany together account for over 40% of international hires (DSIT, 2025l). International recruits are most commonly employed in IC design, software development, research and innovation, and EDA development, underscoring the industry's dependence on global talent.

Overall, the semiconductor industry is characterised by a highly skilled and internationally diverse workforce, with a strong concentration of technical and design-oriented roles. However, the industry's heavy reliance on higher education qualifications, limited vocational entry routes, and persistent gender imbalances present significant challenges for broadening participation and sustaining future talent pipelines. With nearly 40% of the workforce expected to retire within 15 years, the industry faces mounting pressure to attract and train new entrants.

5.4 Summary of findings and identified gaps

Across the six frontier industries, several demographic patterns emerge:

- Each industry is underpinned by a highly educated workforce, with higher education, and particularly STEM subjects, forming the dominant entry pathway for early-career workers.
- Gender diversity is a consistent and significant challenge. In every frontier industry examined, men occupy the vast majority of technical roles.
- Evidence covering age, though limited, suggests a mixed picture. Some industries, such as semiconductors and ACT, face an ageing workforce and imminent replacement pressures. Others, notably AI, draw on a comparatively younger workforce.
- Nationality data, where available, shows that global talent forms a large part of the workforce in both the AI and semiconductors industries.
- Data on other aspects of diversity, such as ethnicity, disability, and socioeconomic background, remain sparse and inconsistent. Where figures do exist, they indicate persistent under-representation of ethnic minorities and disabled people, particularly at senior and leadership levels. Neurodiversity is better captured in cyber security than elsewhere, but comparable evidence is lacking across most other frontier industries.

Amongst these demographic patterns, participants in the qualitative engagement emphasised the issue of gender diversity as being a key priority area for policy intervention.

These patterns also point to a number of evidence gaps:

- **Lack of consistent data across the industries:** The Jobs and Skills Dashboard (2024) is the only dataset that provides comparable demographic data across roles for the frontier industries. There are, however, several limitations with this source:
  - It reports data for roles relevant to each industry (informed by SOC codes), rather than the specific workforce in each industry.
  - The underlying indicators from the dashboard are drawn from different years and populations, some of which are out of date. For example, the education data is from 2019 and covers England only, whereas gender data is from 2022–23 and covers the whole of the UK. This limits comparability across measures.
  - There is no dedicated cyber security category.
- **Uneven evidence across industries:** Beyond the Jobs and Skills Dashboard (2024), DSIT sector studies provide more detailed demographic data for AI, cyber security, and semiconductors, but comparable evidence is limited or absent for quantum, engineering biology, and ACT. The semiconductor study offers the only systematic analysis of age profile and succession trends, highlighting the need for similar evidence in other industries.
- **Limited data on diversity and inclusion:** Gender, sexual orientation, and ethnicity data are often not reported, and there is minimal coverage of disability, neurodiversity, and socioeconomic background across industries. Where data exists, is shows persistent under-representation of women (typically 17 to 22% of the workforce) and ethnic minorities (10 to 15%), especially in technical and leadership roles. However, longitudinal evidence on whether diversity is improving is lacking. Few studies systematically explore the barriers to entry and progression for under-represented groups or assess the effectiveness of diversity interventions.
- **Lack of disaggregated data for technical roles:** The data presented above cover the workforce of each industry as a whole. With almost no disaggregated demographic data for technical professionals, this leaves their demographic characteristics poorly understood.

5.5 Policy recommendations

Based on the findings set out above, we make two policy recommendations relating to workforce demographics (D) within the frontier industries (D1 to D2):

D1 Develop a consistent dataset providing comparable demographic data across technical roles in frontier industries over time. This should include gender, but possibly other characteristics such as sexual orientation, ethnicity, age, disability, neurodiversity, and socioeconomic background. Enhanced workforce demographic

data will improve the ability to track trends in the technical workforce, informing policy interventions across skills planning and research agendas.

D2 Steps should be taken to further explore the causes of gender imbalances and possible solutions. In particular, interventions should be aimed at younger students, after which it likely becomes more difficult to tackle these imbalances.

6 Current technical skills landscape in frontier industries

Building on previous chapters that examined how each frontier industry is defined, the scale of their workforces, and their overall demographic composition, this chapter turns to the evidence on technical skills. It examines the technical roles and capabilities that underpin these industries and where there may be gaps. It reflects on the findings from the rapid evidence assessment and the qualitative engagement.

6.1 Industry-specific evidence on current skills shortages

In this section, we perform a deep-dive into the current skills landscape across each industry.

6.1.1 Advanced connectivity technologies

Evidence from DSIT (2025a) shows how the telecoms workforce covers a range of different occupations, including:

- **Science, research, engineering, and technology professionals:** The largest group, accounting for 21% of employment, reflects the industry's technical foundation, encompassing telecoms and network engineers, AI, software, and security specialists;
- **Customer service occupations:** Representing 15% of the workforce, this highlights the significant customer-facing component of telecommunications services; and
- **Business and public service associate professionals and administrative occupations**: Which respectively make up 12% and 10% of the workforce.

With technical professionals accounting for around one fifth of the workforce, DSIT (2025a) highlight the industry's particular reliance on advanced engineering and research capabilities. These skills are critical for building and maintaining network infrastructure, yet are highly specialised and have been found to be in strong demand across competing industries. For example, many of the foundational skills required for the telecoms and ACT workforce, such as data analytics, software development, and systems engineering, overlap with other technologies, including AI and cyber security.

A key theme in the DSIT (2025i) response to the Telecoms Supply Chain Diversification Advisory Council report is the shortage of skills across the telecommunications industry. The response highlights that these shortages pose a risk to building more diverse and resilient supply chains, especially as the shift toward open and interoperable networks increases demand for combined engineering and software expertise. These findings were corroborated throughout the stakeholder interviews. DSIT attributes these skill gaps to both structural and short-term factors, including limited entry pathways, and the fast-paced emergence of new skills linked to network virtualisation and interoperability (DSIT, 2025i). It is noted that understanding the future skills requirements of the sector is essential to ensure effective interventions.

This is echoed by the UK Telecoms Innovation Network (UKTIN, 2025), which highlights that, with an ageing workforce (around 60% of UK engineers are now over 50), training gaps and a weakening talent pipeline are becoming increasingly significant. Rising demand for fibre and 5G deployment has exposed skills shortages across the country, with recent analysis indicating that 33% of professionals in senior network engineering and operations roles are not yet equipped to adapt to emerging technologies such as 5G and Open RAN (UKTIN, 2025). The talent pool is also highly concentrated in London and the South East, limiting the industry's capacity to scale innovation nationally.

The Workforce Foresighting Hub (2025) report reinforces these findings, showing that the UK telecoms industry faces significant workforce skills gaps, particularly in AI-related functions critical to 5G deployment and network optimisation. While entry-level roles such as data technical professionals require limited AI integration, mid- and senior-level positions increasingly demand advanced expertise in machine-learning, AI systems integration, and digital twin design. Out of 143 future skills needs identified, 19 had no match in current apprenticeship standards, revealing notable deficits across education and training provision. High-priority skills include the ability to integrate AI with telecom infrastructure, design and manage digital twin environments, apply generative AI for customer engagement, and implement MLOps and data governance systems. The report concludes that, without urgent adaptation of degree, master's, and PhD programmes to embed these specialised capabilities, the UK risks slower commercialisation of AI technologies in telecoms and reduced global competitiveness in next-generation connectivity.

Throughout the qualitative engagement, interviewees agreed that the ACT industry is rapidly changing. Interviewees emphasised that new innovations rely on technologies across a range of disciplines, requiring technical professionals to be highly adaptable. A broad understanding of the wider industry is therefore essential to successfully deploy and understand new technological developments. Core requirements for technical professionals to understand include system engineering, connectivity, matters of security and resilience, global telecoms standards, and proficiency with AI-based tools.

Interviewees identified that current skills shortages are driven by technical professionals lacking a broad, cross-disciplinary understanding of the industry. Possible explanations for this included (i) a lack of interaction between different disciplines throughout university degrees, and/or (ii) the difficulty of more senior technical professionals upskilling in line with emerging innovations in the industry.

Throughout the stakeholder interviews and roundtable discussion, participants offered possible solutions for upskilling the workforce in line with rapid technological developments. These included:

- Developing short, targeted courses to upskill new and existing members of the workforce in areas where there are emerging skills requirements. These courses could help to bridge the gap between industry skill requirements and the skills developed by

students throughout their degree courses, whilst also bringing existing members of the workforce up to speed with technological developments; and

- Supporting industry-sponsored apprenticeships to expose students to (i) the industry-wide systems to help develop a broad and cross-disciplinary understanding of the ACT industry, and (ii) more experimental environments to help develop practical skill sets (for example, integration of AI with telecom infrastructure).

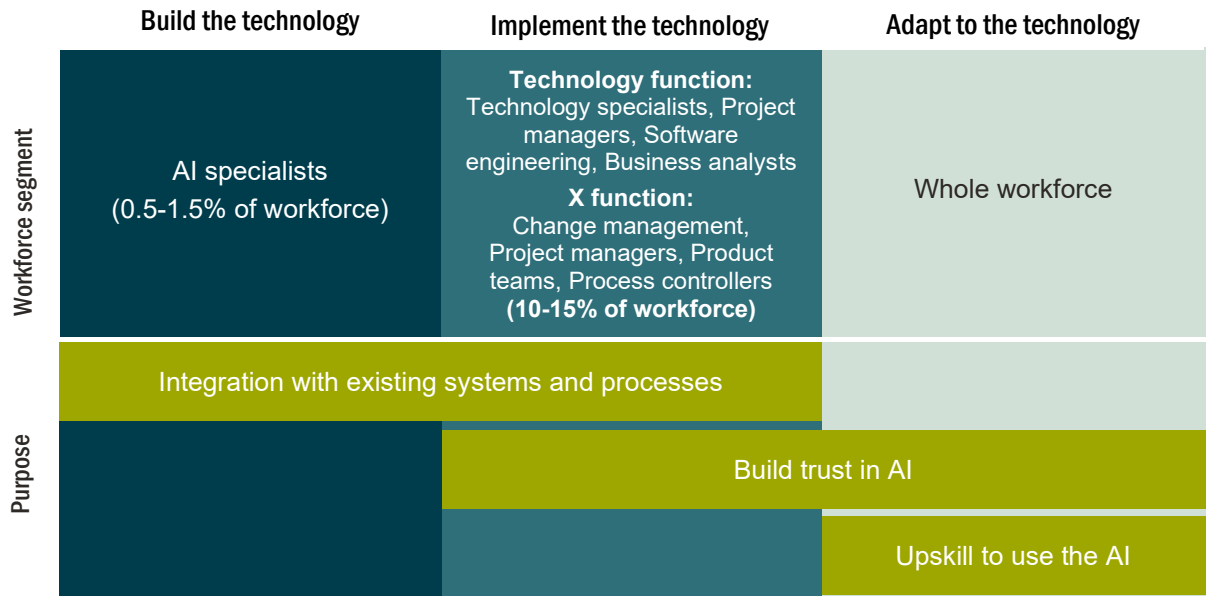
In conclusion, the evidence highlights persistent and evolving skills shortages across the ACT industry, driven by both structural and technological change. The transition toward open and interoperable networks, alongside the integration of AI, is reshaping the skill profile required across engineering, software, and systems disciplines. The literature points to an ageing talent pipeline, with shortages acute in mid- and senior-level technical roles.

6.1.2 Artificial intelligence

The UK AI workforce spans a wide spectrum of roles, from highly technical research and engineering positions to less technical implementation and business-facing roles. Evidence often distinguishes between AI development (for example, creating machine-learning models, typically requiring advanced STEM or postgraduate training) and AI deployment (for example, applying AI tools in business settings, combining moderate technical training with domain expertise) (Ipsos Mori, 2021). Yet, as adoption accelerates, these boundaries are increasingly blurred. Traditional software engineers and IT professionals now need at least some familiarity with AI, while AI technical professionals themselves are expected to acquire industry-specific knowledge in fields such as finance, healthcare, and law.

This distinction between roles building new technologies and those deploying it is shown in Figure 13. Developed by the Financial Services Skills Commission (2025), the figure estimates the share of the UK workforce in each category. At one end, there are AI specialists who develop the core technologies such as machine-learning models, generative AI applications, and natural language processing. These account for between 0.5-1.5% of the workforce. A larger group - around 10-15%, is involved in implementing AI into existing processes. These include technology specialists, software engineers, project managers, and business analysts. Finally, there is the wider workforce who adopt AI tools in their roles.

Figure 13 AI skills and the share of workforce working in each segment



Source: Adapted from the Financial Services Skills Commission (2025)

A wide range of evidence consistently highlights the increasing pressure on the UK labour market to meet growing demand for building and implementing AI technology. For example, the Financial Services Skills Commission (2025) find that AI-related data and software roles are among the hardest to fill, reflecting the extent of competition for talent required to both build and implement AI solutions. This is echoed by the Office for National Statistics (2025), which cites how many businesses are experiencing delays in implementing AI programmes because of insufficient expertise. Similarly, the Bank of England (2024) find that 81% of firms identify a lack of specialist talent as a constraint to using AI, with Capital Economics (2022) reporting that the most commonly cited external barrier to the successful adoption of AI technologies was the shortage of AI and data science skills.

These findings are mirrored in wider labour market data. A LinkedIn News analysis of the fastest-growing jobs in 2023 identified roles akin to machine-learning engineers among the top 25 emerging positions in the UK over the previous six years (LinkedIn News UK, 2023). In its 2024 update, LinkedIn News ranked artificial intelligence engineers among the top ten fastest-growing roles in the country (LinkedIn News UK, 2024), reflecting sustained momentum in employer demand.

These findings were echoed throughout the qualitative engagement, where interviewees emphasised skills shortages in relation to AI engineering. In particular, interviewees highlighted that there is an increasing need for businesses to build and manage large data infrastructure to train in-house AI tools and maintain data sovereignty. However, since the workforce has become increasingly dependent on the cloud for data storage, there is a growing shortage of technical professionals with sufficient expertise in designing and maintaining these large data structures themselves.

The shortages reported also extend beyond specialists and technical professionals, affecting the whole workforce's ability to adapt and leverage AI effectively. A recent survey of 1,000 hiring managers conducted by Resume Genius (2025) found that 81% now consider AI-related skills a hiring priority, with this among the most sought-after capability in 2025. This is echoed in research from PwC (2025), which found that demand for workers with AI skills is increasing across various industries, being highest in the information and communication sector.

Similar themes emerged throughout the qualitative engagement, where participants across all industries emphasised the increasing need for technical professionals and industry leaders alike to be AI-literate to facilitate widespread AI adoption. In particular, participants emphasised that, in order to protect scientific reproducibility and safety standards, individuals will need to be equipped with strong appraisal skills to validate the outputs of AI.

These skills shortages appear to be negatively impacting UK businesses. For example, DSIT's annual studies of the AI industry consistently find that more than a quarter of businesses cite AI technical skills shortages as a barrier to growth. Evidence from SAP (2025) reinforces this picture, showing that over a third (34%) of high-growth organisations struggle to find, attract and retain AI-skilled staff. Similarly, Ipsos's (2020) review of the UK AI labour market found that 62% of firms faced technical skills gaps, with 35% of businesses reporting that a lack of employee technical skills had prevented them from achieving business goals and 49% reporting that applicants' inadequate technical capabilities had constrained growth. Finally, Digital Catapult and the National Innovation Centre for Data's (2025) study on AI adoption suggests that 16% of companies report insufficient AI-related expertise and skills as hindering adoption, thereby slowing down technological growth.

Surveys also shed light on the nature of these technical skill gaps within the workforce. Ipsos (2020) identified deficits in understanding of AI concepts and algorithms (55%), programming skills and languages (52%), software and systems engineering (52%), and user experience (51%). More recent analysis from the University of Birmingham (2024) shows that demand is highest for advanced digital skills associated with software development, particularly in AI and machine-learning, which are becoming increasingly critical across industries. Regional patterns are also visible, with devolved nations reporting the most severe shortages, with the South West and London being highlighted as facing significant pressure in advanced digital skills (University of Birmingham, 2024).

Additionally, Skills England's (2025b) report examines the upskilling requirements, challenges, and opportunities for AI adoption across ten growth industries[11], and presents tools designed to help employers and training providers respond effectively. The report identifies the skill gaps and barriers for each sector, finding that both progress and skill requirements differ across sectors. Some sectors are relatively mature yet still have gaps in ethics, governance, and interpretability, while others require better infrastructure, training,

[11] Digital and technology; health and social care; financial services; advanced manufacturing; construction; professional and business services; creative industries; clean energy industries; defence; life sciences.

and workforce support. The pace of adoption, specific skills required, and workforce readiness differ both across and within industries, influenced by organisation size, access to training, and geography. Small and medium-sized enterprises (SMEs) are hit hardest by constraints on capacity, cost, and awareness, which hampers structured AI training and limits the gains from innovation.

The report also highlights that marginalised groups, such as women in under-represented industries, older workers, low-income adults, and people with limited digital skills, face greater barriers to building AI skills. There are also clear regional disparities, as urban areas and innovation hubs benefit from stronger training ecosystems, whereas rural and economically disadvantaged places often have limited or no AI-specific provision.

Skills England also highlights several structural barriers to AI upskilling, including:

- Muddled and inconsistent definitions of “AI skills” that confuse employers, providers, and learners;
- Weak baseline digital literacy in less digitally mature industries;
- A fragmented training system with poor coordination and unclear progression routes;
- Lengthy, complex curricula that adapt too slowly to new AI tools and sector-specific needs;
- High training costs and precarious funding (especially for SMEs and community providers); and
- Limited employer insight into the AI skills their workforce actually requires, particularly among smaller firms and in early-stage adopter industries.

Overall, the evidence on the current AI technical skills landscape suggests that:

- There is a skills shortage in core technical areas such as machine-learning, generative AI, and data science. Only a small fraction of the workforce is engaged in developing AI models and systems, and firms report strong competition for this limited talent pool.
- Surveys by the Office for National Statistics (ONS), Bank of England, and DSIT show that a lack of applied technical skills and implementation capacity is among the most frequently cited barriers to AI adoption and business growth.
- Beyond technical specialists, the evidence points to a systemic need for AI literacy and digital skills across the wider workforce. Employers increasingly expect workers to collaborate effectively with AI tools, yet deficits in data handling, programming, and analytical skills remain widespread.
- The evidence indicates that demand for AI skills is increasing across all industries, while Skills England (2025b) highlights that progress and skill needs differ both across and within industries, influenced by factors such as organisation size, access to training, and geography.
- Most of the identified skill gaps relate to the deployment of technologies rather than their development. The available evidence focuses on the challenges firms face in integrating

AI systems into existing operations, including shortages of data scientists, software engineers, and project managers capable of applying AI solutions at scale. By contrast, there is far less evidence on shortages in development-focused skills, such as those required to design, build, and maintain the underlying AI infrastructure. This imbalance suggests that, while adoption capacity is well-documented, the upstream technical foundations needed to support continued AI innovation remain poorly understood.

Throughout the qualitative engagement, participants offered possible solutions for upskilling the workforce in line with the emerging requirements of the AI industry. Stakeholders suggested several changes that could help align educational pathways more closely with industry skills needs:

- Supporting industry-sponsored apprenticeships to expose students to real-world data and AI infrastructure, helping to develop expertise amongst AI engineers in line with industry needs;
- Linking Centres for Doctoral Training (CDTs) with real-world datasets to improve skills around the management of large data infrastructure; and
- Providing short, targeted courses aimed at upskilling the wider workforce to improve basic AI literacy and skills around AI appraisal.

6.1.3 Cyber security

DSIT's Cyber Security Skills in the UK Labour Market report (2025e) highlights persistent technical skills gaps within the cyber security workforce. Around three in ten firms (28%) reported that shortcomings in the technical skills of their existing employees were affecting their ability to meet business objectives. This figure rises to almost half (46%) when employers consider applicants who lack essential technical skills. The most frequently cited areas of weakness were auditing and assurance (23%), digital forensics (22%), and cryptography and communications security (22%).

While the impact of skill deficiencies among job applicants has remained relatively stable since 2020, the proportion of employers reporting technical gaps amongst their current workforce has grown steadily, from 18% in 2021 to 28% in 2025. This indicates a challenge in upskilling existing staff. From a hiring perspective, the report also finds that one third (33%) of cyber industry vacancies were considered hard to fill in 2025, down from 55% in 2023 and 37% in 2022. While this demonstrates an easing of hard-to-fill vacancies, over half of employers still cite a lack of technical skills as one of the main reasons for recruitment difficulties. In addition, interviews with technical professionals from universities reported that limited resources to provide comprehensive technical training to non-specialist applicants poses a significant constraint on filling vacancies, requiring employers to hire from a smaller pool of specialists rather than those from more generic backgrounds. Similarly, stakeholders reported low pay as a major constraint on filling vacancies at universities.

DSIT (2025e) also estimate the annual cyber workforce gap, measuring the shortfall between the number of people the UK needs in cyber roles each year and the number

actually entering those roles. They estimate that the UK cyber workforce comprised approximately 143,000 individuals in 2024. Based on an assumed 4% outflow rate (around 5,700 exits)[12] and an assumed 5% growth rate in demand (equating to 7,200 new roles), the total supply requirement for 2025 was estimated at around 12,900 new entrants. Against current inflows of 9,300, this translates into a net shortfall of around 3,800 workers per year. This gap is broadly consistent with 2024's estimate (3,500) and is significantly lower than earlier figures reported in 2023 (11,100) and 2022 (14,100).

Despite this, DSIT concludes that the technical skills gaps within the existing workforce continue to grow. They identify the strengthening of advanced technical skills in areas such as cryptography, digital forensics, and artificial intelligence as critical to the UK's cyber security industry.

Overall, while recruitment pressures in cyber security appear to be easing, underlying technical skills gaps remain a significant constraint on workforce capability. Evidence suggests that shortages are shifting from entry-level hiring towards gaps in the existing workforce, reflecting challenges in continuous upskilling and retention. Limited evidence exists on whereabouts in the ecosystem (such as digital forensics, assurance, or secure systems design) these deficits are most acute.

6.1.4 Engineering biology

Engineering biology draws on multiple disciplines and therefore presents a complex training and skills challenge (DSIT, 2023c). Evidence indicates that the UK faces a persistent shortage of skilled technical professionals, spanning both the technical and doctoral levels (Prime Minister's Council for Science and Technology, 2023). In DSIT's National Vision for Engineering Biology consultation, respondents were asked which priorities from the Science and Technology Framework mattered most to the engineering biology community. "Talent and skills" emerged as the second-highest priority overall, particularly amongst academics (DSIT, 2023c).

A recurring concern across responses to the DSIT consultation was the shortage of lab technical professionals in both academia and industry (DSIT, 2023c). Contributing factors include low pay, limited career progression, and low visibility of technical pathways as viable long-term options. Similar themes emerged throughout the qualitative engagement, where technical professionals representing universities highlighted that low pay, limited career progression and the short-term nature of fixed-term contracts dissuade prospective technical professionals from entering these roles.

Stakeholders responding to the DSIT (2023c) consultation also reported that the availability of skilled bioprocessing specialists was well below industry requirements, particularly in the design, operation, and maintenance of bioprocessing facilities and equipment. Demand for

[12] The assumed 4% outflow rate is based on survey data for the proportion of staff being dismissed, made redundant or retiring.

these technical skills exceeds supply at every level, from workshop apprentices to engineers capable of designing and constructing biomanufacturing plants (DSIT, 2023c). These views were echoed throughout the qualitative engagement, with interviewees describing how the industry will increasingly require more technical professionals and bioprocessing engineers to support the growth of biomanufacturing (and how these technical professionals are already in short supply).

DSIT (2023c) also identified a broad mix of technical and non-technical skills needed to develop, scale, and commercialise engineering biology products. The question focused on which skills are important, rather than on their current availability in the workforce. In response, 41% highlighted fundamental biology knowledge and practical laboratory expertise as essential, while 92% pointed to at least one interdisciplinary skill such as data analysis, computational methods, business development, AI/machine-learning, or automation. Around one third (32%) also stressed the importance of communication and collaboration across disciplines. Frequently highlighted skills for scale-up and manufacturing included expertise in fermentation science and bioprocessing expertise (DSIT, 2023c).

Practical skills were also raised as important throughout the qualitative engagement (for example, proficiency in coding, applying AI tools, and computational and lab-based skills) as well as a detailed background in molecular and cell biology. Interviewees noted that current shortages reflect gaps in practical skills rather than weaknesses in fundamental biological understanding, and that technical professionals in the engineering biology industry lag behind their counterparts in other industries in AI-handling and coding expertise.

The House of Lords (2025) report “Seizing the Opportunity of Engineering Biology” likewise found that technical skills are in short supply, and that retention remains a major challenge. Employers consistently reported difficulties recruiting people with hands-on expertise in bioprocessing, fermentation, and purification. These skills are fundamental to translating technologies from laboratory research into industrial-scale production (House of Lords, 2025).

In conclusion, the evidence reviewed points to a widespread shortage of technical professionals across the engineering biology industry. Persistent skills gaps are most pronounced in technical and biomanufacturing roles, particularly in fermentation, purification, and process engineering, where demand continues to exceed supply. However, these gaps are not quantified.

6.1.5 Quantum technologies

Wilkes (2025) highlight that quantum technologies can be split into three categories: (i) quantum sensing, (ii) quantum computing, and (iii) quantum communication. Workforce Foresighting Hub (2025) notes that the effective deployment of quantum sensing technologies depends on developing a workforce able to bridge the divide between scientific research and commercial application. The Quantum Taskforce (2025k) reports that some of the largest long-term increases in demand for skills are expected to arise in roles that enable

the adoption of quantum computing and the development of use-case applications across industries. Sectors most likely to be affected, such as finance, pharmaceuticals, logistics, and materials science, are already beginning to upskill in anticipation of future advances in quantum hardware and software. While the timeline for achieving technological milestones such as error-free or general-purpose quantum computing remains uncertain, the Taskforce suggests that their realisation could trigger a rapid surge in demand for quantum-literate professionals in both specialist and user industries (DSIT, 2025k). This pattern may mirror the sudden acceleration in global demand for AI expertise following the breakthrough of large language models in 2022 (McKinsey, 2022). Consequently, McKinsey (2022) identifies a pressing need to better define the skills required to adopt and apply quantum computing across the economy and to develop clear training pathways to upskill existing workers.

The Quantum Taskforce Report (DSIT, 2025k) outlines the key scientific, engineering, and technical skills required to support the growth of the quantum industry. Some of the key findings are:

- **Quantum specialists form a distinct group within the industry, comprising roles that require advanced, highly specialised knowledge of quantum science**. These positions are typically filled by individuals with PhDs in physics, mathematics, or closely related fields, often combined with postdoctoral or industry experience. The skills required are niche and evolve rapidly as the science advances, making it difficult to pin down a comprehensive taxonomy of specialist roles without it becoming quickly outdated. The Taskforce highlights how the UK benefits from a strong pipeline of graduates in relevant subjects, placing it in a relatively good position internationally. However, the supply of candidates with deep quantum expertise remains limited on a global scale, while demand for their skills is set to grow for at least the next decade. As many quantum technologies are still at low technological readiness levels, the industry will continue to depend heavily on these specialists to sustain progress.
- **As quantum technologies move towards scaling and commercialisation, engineers and technical professionals will play an increasingly important role in addressing challenges such as improving performance, scaling quantum bit (qubit) systems, integrating sensors, and ensuring consistent manufacturing quality.** Most of these positions will not require deep quantum expertise, but they will demand a baseline of quantum awareness alongside domain-specific training. Recruitment into these roles is already proving difficult, partly due to limited awareness of quantum career pathways and the perception that significant quantum knowledge is essential. Broader engineering shortages across the economy are also intensifying the challenge as competition for these skills grows across multiple sectors. It is noted that there is a need to explore role-specific requirements in greater detail.
- **The Taskforce suggests that there is a general shortage of technical professionals across the quantum industry and the wider economy in the UK, with the gap especially pronounced within universities and research institutions.** It also notes that further analysis is needed to gain a clearer understanding of the situation in institutions engaged in quantum research.

In addition to a base-level understanding of quantum physics, the qualitative engagement highlighted that technical professionals are primarily required to have practical, lab-based skills. These include the maintenance of vacuum systems and dilution refrigerators, as well as basic electrics and plumbing. Skills shortages were highlighted in these areas. This was attributed to students receiving limited exposure to practical environments or cleanrooms until PhD level. Technical professionals at universities also cited low pay and job insecurity as factors dissuading technical experts from working in the quantum technologies industry, worsening pre-existing shortages of technical professionals.

In conclusion, while the UK is well-positioned in the quantum technologies sector, shortages persist in both highly specialised quantum science roles and applied technical and engineering positions needed for commercialisation. These shortages are not, however, quantified by the literature. Stakeholders suggested that providing specialised degree courses that train technical professionals with the relevant practical skills, and which combine parts of physics, electronics, chemistry, bioscience and computing degrees together, could help reduce these shortages. In their view, this would create a viable pathway into the industry for technical professionals who do not have deep quantum expertise, but who have a sufficient baseline of quantum knowledge that can be supplemented with domain-specific training.

6.1.6 Semiconductors

DSIT's UK Semiconductor Workforce Study (2025l) estimates that the industry employs around 27,000 people, with nearly 69% working in technical roles.[13] It is the only DSIT study across the frontier industries to explicitly distinguish the share of technical roles within the workforce[14]. The majority (64%) of these technical workers specialise in design-related activities such as IC design, software development, and research and development, while a smaller, but still significant, group (36%) are employed in manufacturing and materials-focused roles. The DSIT (2025l) study highlights workforce shortages as one of the most pressing challenge facing the industry, with the current inflow of new entrants being already insufficient to offset retirements and attrition. It estimates that around 2,245 individuals enter the workforce each year (8.2% of the total), while annual outflows reach approximately 2,400 (8.8%), leaving the industry operating with a net deficit even before accounting for future growth.

Career patterns show that technical employees typically hold four to five roles over the course of their careers (DSIT, 2025l). Those in manufacturing roles tend to stay longer in post, while employees in design and R&D move more frequently between jobs. Large firms

[13] The technical roles identified include IC design engineers, software development, EDA developers, process integration and manufacturing, product management, research and innovation, quality and testing, manufacturing operations, manufacturing systems, equipment and facilities, hardware design, materials science and engineering, radio frequency/wireless design, and electrical engineers.

[14] The DSIT ACT Market Scoping Analysis (2025) also distinguishes the proportion of technical professionals; however, its estimates apply to the wider telecommunications industry rather than specifically to advanced connectivity technologies.

such as Arm, Intel, Seagate and Huawei, all of which have UK headquarters or major UK operations, have been especially important as gateways into the industry, often providing the first opportunities for new talent.

The shift of high-volume manufacturing to Asia during the 1990s and 2000s left the UK with a smaller but highly specialised workforce (House of Commons, 2022). However, the industry's workforce is ageing, and firms are increasingly struggling to upskill and retain experienced technical staff. During the stakeholder interviews, participants also cited the shift of software development and manufacturing to Asia as a prominent challenge for training new technical professionals due to a lack of domestic industry. Around 39% of current employees (approximately 10,700 people) are expected to reach retirement age within the next 15 years, equivalent to over 700 departures per year (DSIT, 2025l). This poses a significant challenge for succession planning and the transfer of specialist knowledge. The most acute replacement pressures are expected in manufacturing, IC design, EDA development, and product management, where between 13% and 30% of the existing workforce is projected to retire by 2040 (DSIT, 2025l).

DSIT's (2024) sector study found that 90% of companies surveyed reported moderate or acute shortages of talent to fill key technical roles, especially R&D scientists, manufacturing/process engineers, and IC design engineers. Anecdotal evidence suggests that some strategically important UK firms are operating with headcounts around 10% below requirements due to recruitment challenges (House of Commons, 2022). These sentiments were validated throughout the qualitative engagement, where interviewees reported a shortage of technical professionals generally, with applicants often having unsuitable skillsets. Representatives from universities also cited low pay as a deterrent to better-suited graduates entering the industry.

Participants in the qualitative engagement reported skills shortages across the current semiconductor production line. However, participants particularly emphasised that shortages occur because technical professionals lack the required practical skills. In their view, this is because students receive little exposure to experimental environments until late in their education (i.e. at the PhD level) due to (i) the costly nature of running cleanrooms, and (ii) insufficient funding for access to cleanrooms to be widespread across undergraduate and master's students. Stakeholders also emphasised that, despite often being the first opportunity to gain exposure to practical environments, a PhD-level qualification is often not required for technical roles. Therefore, alternative routes whereby students could gain the relevant practical skills without needing to pursue a PhD would be more efficient.

Looking ahead, the skills profile of the semiconductor industry is expected to evolve rapidly, driven by advances in digitisation and connectivity. In a survey for DSIT (2024l), around 60% of companies anticipate demand for emerging skillsets in areas such as design engineering, artificial intelligence, machine-learning, modelling, and data engineering. This shift reflects the increasing convergence of semiconductor design and advanced digital technologies, further widening the skills gap. These trends were also cited throughout the qualitative engagement.

The Manufacturing Technology Centre (MTC) (2025) highlights longstanding weaknesses in the UK's electronics and engineering education pipeline. Too few students pursue electrical and electronic engineering, resulting in an insufficient supply of graduate engineers to sustain innovation, particularly in semiconductor manufacturing and embedded systems design. Around 22% of employers in the industry report difficulty recruiting engineering graduates, while women account for just 11% of the UK's electronics workforce (MTC, 2025). The report concludes that, without targeted interventions, the shortage of graduates and gender imbalances are expected to intensify.

Overall, there are acute shortages of process and design engineers, IC designers, manufacturing and embedded systems engineers, and R&D scientists in the semiconductors industry. The education pipeline for electrical and electronic engineering remains weak, contributing to a structural talent deficit. Firms report growing demand for data engineering, AI, and digital design skills as semiconductor technologies converge with advanced computing.

Stakeholders suggested three possible solutions for addressing challenges in the semiconductors workforce:

- Recruiting from overseas to bridge current shortages of technical professionals in the short term;
- Improving awareness amongst school children of the semiconductors industry and technical roles in the long term; and
- Increasing funding for, and improving access to, practical and experimental environments such as cleanrooms for pre-PhD-level students.

6.2 Cross-industry themes

6.2.1 Technical professionals face barriers when entering and progressing through the industries

Throughout the qualitative engagement, participants consistently highlighted two key barriers technical professionals face when entering and progressing in each industry:

- **Universities and research institutes offer relatively low salaries and unattractive working conditions to technical professionals.** This includes internal structures that make progression difficult, as well as job insecurity from fixed-term contracts. As a result, universities and research institutes struggle to attract new graduates as well as retain their senior staff members, with technical professionals leaving to industry-based roles or other sectors.
- **There is a lack of awareness amongst students as to the existence and nature of technical roles available across the industries**. As a result, shortages are created by losing prospective technical professionals to other industries or roles that are better advertised.

Stakeholders highlighted that these barriers are causing vacancies to go unfilled. To help improve the supply of prospective technical professionals, interviewees emphasised the importance of improving working conditions, particularly in universities and research institutes. In addition, participants suggested taking steps to raise awareness of technical routes amongst children before they start to specialise. For example, in order to provide early opportunities to engage with the industries, participants suggested:

- Supporting work experience programmes for students to provide early opportunities;
- Offering 'experience days' to children through partnerships with institutions in frontier industries; and
- Showcasing technical opportunities to young students through school visits.

6.2.2 Shortages of practical skills, innovative thinking and proficiency with AI are common across industries

Beyond the industry-specific skills requirements and shortages outlined in Section 6.1, stakeholders revealed a number of common skills across industries experiencing shortages:

- **Practical and applied skills**: Stakeholders emphasised that, due to the costly nature of operating practical and experimental environments at universities, students often do not have the opportunity to develop these skills until they reach PhD level or enter the industry.
- **Proactivity and innovative thinking:** Technical professionals from the ACT, AI, and engineering biology industries cited an increasing reliance on pre-existing software, AI or protocol-based work. As a result, newer technical professionals have less exposure to opportunities to build technologies from scratch, resulting in growing skills gaps relating to being proactive and thinking critically.
- **Proficiency with applying AI tools:** Representatives from all six frontier industries reported that technical professionals are insufficiently equipped to use AI tools, have poor AI literacy and ability to validate the outputs of AI. Without these skills, frontier industries may struggle to develop further.

The qualitative engagement highlighted potential opportunities to increase students' exposure to practical settings, innovation-based tasks, and tasks involving AI. These opportunities primarily focused on aligning educational pathways more closely with the skills requirements of industry. Suggestions included:

- Supporting industry-sponsored apprenticeships for university students;
- Linking CDT courses with real-world datasets and exercises around the management of large data infrastructures; and
- Providing short, targeted courses to upskill new and existing members of the workforce in areas where there are emerging skills requirements (for example, using AI tools).

- Supporting training at the SME level, who are often at the cutting-edge of new technologies.

6.2.3 Regional imbalances are a major structural issue

Across the six frontier industries, the evidence suggests that skills are often concentrated in specific areas that have received higher levels of public or private investment. This leads to skills shortages in other parts of the UK. For example, the Royal Academy of Engineering's (2025) report on the state of UK deep tech suggests that 80% of deep tech venture capital investment in 2025 was targeted in the Golden Triangle (between London, Cambridge and Oxford). Participants at the roundtable discussion echoed these concerns around public and private support being unevenly distributed geographically, emphasising that this creates difficulties in attracting and retaining skills in certain parts of the country (with the North of England often cited).

DBT's (2025a) Industrial Strategy paper suggests that developing skills hubs across a number of targeted regional clusters is central to growth. In particular, the report highlights plans to 'unlock the potential of Digital and Technology clusters' in multiple cities across the UK, including Glasgow, Edinburgh, Cardiff, Birmingham, Bristol, Oxford, and London. In a similar vein, participants recommended that regional skill clusters should be identified and talent pipelines developed in those local areas to facilitate growth beyond the Golden Triangle.

6.3 Summary of findings and identified gaps

Across the frontier industries, several common themes emerge:

- **Shortages of technical professionals and engineers:** Persistent shortages exist at multiple levels of the technical pipeline. These range from entry-level technical professionals supporting laboratory, manufacturing, and testing functions to specialist engineers developing, integrating, and deploying advanced technologies. These shortages are often compounded by an ageing workforce in certain industries, limited visibility of technical career routes, and competition for talent across industries.
- **Limited quantitative information covering technical professional shortages:** Only the semiconductor has disaggregated information on the number of technical professionals working in the industry. Furthermore, none of the frontier industries report data for technical professionals specifically, covering:
  - The number and characteristics of technical professional roles, disaggregated by role;
  - Career progression and occupational mobility; or
  - Workforce ageing and retirement.
- **Rapidly evolving skill requirements:** Technological change, such as the integration of AI and automation, is reshaping the technical competencies demanded by roles across

all industries. The need for continuous upskilling and reskilling is therefore a recurring theme.

- **Technical professionals face barriers when entering and progressing through industries:** Cross-industry barriers exist in terms of (i) a lack of awareness of the frontier industries, and (ii) poor working conditions in universities and research institutes.
- **Shortages in practical skills, innovative thinking and handling AI tools:** Multiple industries suffer from technical professionals having insufficient practical and applied skills, proactivity and innovative thinking, and proficiency in applying AI tools and validating their outputs.
- **Insufficient alignment between education and industry needs:** Existing further and higher education provision does not yet fully match the skills required in frontier industries. Employers report gaps in practical and interdisciplinary skills, particularly in combining engineering with computing, AI, and data science. Apprenticeships, degree apprenticeships, and conversion courses remain under-scaled relative to demand.
- **Regional imbalances:** Public and private investment is unequally distributed geographically, resulting in skill shortages being concentrated in parts of the UK outside of the Golden Triangle.

These themes point to several evidence gaps, including:

- **Partial and uneven evidence on skills shortage:** Existing studies tend to identify headline skill gaps but provide limited granularity on which specific occupations, qualification levels, and technical functions are most affected. This makes it difficult to distinguish between shortages of high-level engineers, mid-level technical professionals, and entry-level support roles. While engineers are consistently in short supply across industries, few studies disaggregate between different engineering disciplines or technical professionals, leaving significant uncertainty about where the most acute pressures lie.
- **Lack of systematic mapping of future skills gaps:** Across frontier industries, a more robust, data-driven mapping of current and emerging skills needs is required. Evidence gaps persist, particularly regarding technical roles and interdisciplinary capabilities. The interim report by Skills England (2025c), which sets out the UK Standard Skills Classification and provides a hierarchical framework for categorising the skills required for competent performance of specific job tasks, is likely to offer a useful basis for developing a data driven mapping of current and emerging skills in the Digital and Technologies sector.
- **Challenges understanding workforce dynamics and future replacement needs:** Several industries report ageing workforces, yet there is little systematic analysis of retirement risks, succession planning, or inflows of new entrants. Evidence is also limited on how technological convergence, such as the integration of AI into telecoms, the application of automation in manufacturing, or the growing overlap between quantum and computing has changed skill requirements or created new hybrid occupations. Technical pathways in particular remain poorly defined and under-

measured, with little understanding of how individuals enter, progress, or transition across frontier industries.

6.4 Policy recommendations

Based on the findings set out above, we make seven policy recommendations relating to the current skills landscape (CS) within the frontier industries (CS1 to CS7):

CS1 Detailed and consistent information quantifying technical skills shortages and vacancies should be collected to enable policy responses to be effectively targeted. The data should be sufficiently granular to identify the specific occupations, qualification levels, skills and technical functions most affected. While the available evidence points to persistent skills gaps, their precise scale remains unclear.

CS2 A robust, data-driven mapping of current and emerging technical skills should be completed. While the qualitative engagement points to themes such as a lack of practical and applied skills, proactivity, innovative thinking, and proficiency with handling AI tools (which may be early places to focus), gaining a comprehensive view across industry is key.

CS3 A systematic analysis of retirement risks, succession planning, and supply of prospective technical professionals should be conducted for each frontier industry. By understanding workforce dynamics and future replacement needs, government can then proactively address potential challenges before they arise.

CS4 Steps should be taken to improve the pipeline of skills and awareness of technical routes early, before children start to specialise. This may help break down barriers and improve the supply of prospective technical professionals.

CS5 The working conditions of technical professionals should be improved. This includes potentially supporting improved pay, progression and job security of technical professionals in the higher education sector in particular.

CS6 Ensure there is a level playing field in funding and support across regions. The qualitative engagement indicated that developing regional skill clusters and talent pipelines, and supporting SME ecosystems beyond the Golden Triangle could help address this.

CS7 Align educational pathways more closely with industry skill needs. This includes a stronger focus on developing students' practical skills, innovative thinking, and proficiency with handling AI tools.

7 Future shortages of technical professionals across the frontier industries

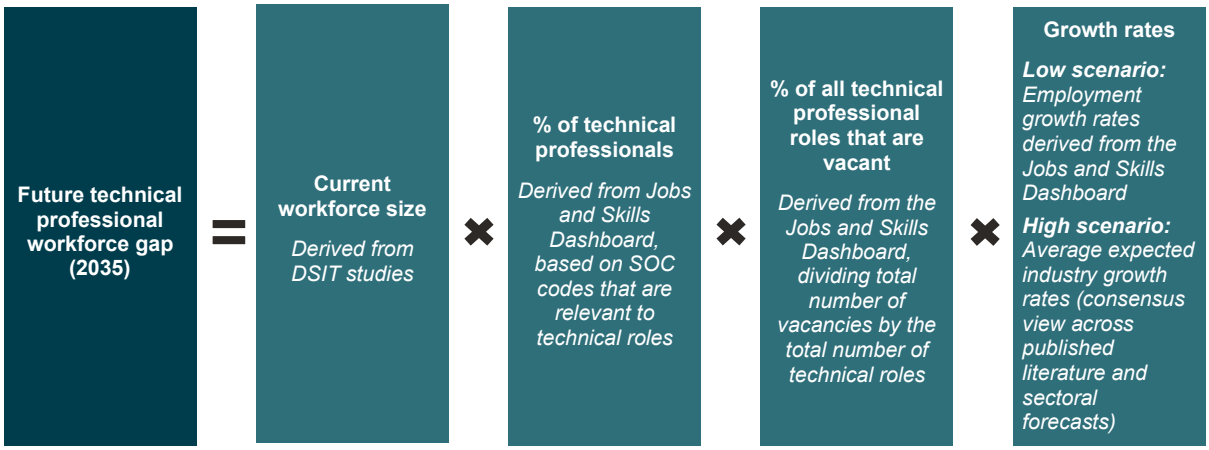
So far, this report consistently highlights a current, pressing need for technical professionals across the frontier industries. While there is some evidence on the current composition and characteristics of each industry's workforce, there remains limited understanding of how the demand and supply of technical professionals will evolve over time and the specific skills that will be required. To help address this evidence gap, high-level projections of how current shortfalls in the technical workforce may evolve over the next ten years have been developed.

This chapter first outlines the methodological approach to estimating the shortage of technical professionals, before describing the indicators and data sources that underpin the analysis. It then summarises the growth rate assumptions applied under alternative scenarios, and concludes by presenting the modelled results and comparing them with available evidence from the literature and qualitative engagement.

7.1 Forecasting methodology

To forecast the current gap in technical professionals, we developed a four-stage methodology. This is summarised in Figure 14, with further detail on each step provided below.

Figure 14 Summary of four-step forecasting methodology



Source: Frontier Economics

7.1.1 Step 1: Identify the total number of roles in each industry

Estimates of the current workforce size in each industry are drawn from the DSIT sectoral studies presented in Chapter 4.[15] Estimates for years prior to 2025 were uprated to 2025 baseline values using projected industry employment growth rates from the Skills Imperative 2035 forecasts (Jobs and Skills Dashboard, 2024).

7.1.2 Step 2: Estimate the proportion of roles which are technical

Within the occupations the Jobs and Skills dashboard identifies as relevant to each industry, we identify those roles considered technical as follows (to account for the uncertainty over classification):

- **Lower bound:** Includes only those roles with 'technician' explicitly in their title.
- **Upper bound:** Also includes roles with 'engineer', 'scientist', and 'trainer' in their title.

Using these two rules, the percentages of all roles classified as technical in each industry was calculated (see Table 4 below). These proportions were then cross-referenced against the available literature and alternative data sources to check for consistency, where available.[16] For instance, the DSIT (2025) Semiconductor Workforce Study finds that around 69% of all roles are technical, closely aligning with the upper bound estimate of 77% used in this analysis. Similarly, the DSIT (2025) ACT Market Scoping Analysis reports that approximately 21% of telecommunications roles are technical, which is broadly consistent with the upper bound estimates presented below.

Table 4 Estimated proportion of roles which are technical

Frontier industry	Percentage of roles classified as technical
ACT	3 - 22%
AI	21%
Cyber security	15 - 28%
Engineering biology	14 - 45%
Quantum technologies	12 - 45%
Semiconductors	39 - 77%

Source: Frontier Economics analysis of the Jobs and Skills Dashboard (2024)

Note: AI only has one estimate, because there were no roles with the term "technician" identified by the Jobs and Skills dashboard for this industry

[15] A key limitation of the DSIT studies is that they do not include estimates for those working outside of the private sector.

[16] Annex A provides the breakdown of occupations included in the lower bound and upper bound for each of the frontier industries.

As explained in Chapter 5, the Jobs and Skills Dashboard employment estimates for each role are economy-wide, rather than specific to those employed within each frontier industry. Future research should seek to determine the precise roles and employment numbers by role within each industry and update this with more recent data where possible.[17]

7.1.3 Step 3: Estimate the number of technical professional vacancies

To approximate the existing gap in technical professionals, vacancy data from the Jobs and Skills Dashboard (2024) was used.[18] The total number of vacancies in technical professional roles was then divided by the total number of technical professional roles estimated in Step 2. This provided an estimated upper- and lower- bound proportion of all technical roles that are currently vacant (see Table 5 below).

Table 5 Estimated proportion of technical roles that are vacant

Frontier industry	Percentage of technical roles vacant
ACT	2.7 – 4.0%
AI	3.1%
Cyber security	2.6 – 2.8%
Engineering biology	2.7 – 4.4%
Quantum technologies	2.7 – 3.0%
Semiconductors	4.1 - 4.4%

Source: Frontier Economics analysis of the Jobs and Skills Dashboard (2024)

To calculate the current gap in technical professional roles for 2025, the total workforce for each industry in Step 1 was multiplied by the estimated share of the workforce in technical roles in each industry from Step 2. This provides an estimated size of the technical workforce. This figure was then multiplied by the share of all technical roles that are vacant. This yields an indicative estimate of the current shortfall in technical professionals within each industry.

17 Current data is drawn from the 2022–2023 Annual Population Survey.

18 This is based on the 2022 Employer Skills survey, which uses the SOC 2010 system for roles. While these are not directly comparable with the more recent SOC 2020 codes which were used to estimate proportion of technicians in Step 2, it provides the most comprehensive available indication of unmet occupational demand. Similar roles using both systems were, however, identified.

7.1.4 Step 4: Project the number of technical professional vacancies to 2035

As the UK's Modern Industrial Strategy covers a ten-year period (DBTa, 2025), we model the evolution of current technical professional vacancies over that timeframe. To reflect the significant uncertainty over how these might evolve, we include two growth scenarios:

- **Lower-growth:** This uses employment growth projections for the technical occupations identified from the Jobs and Skills Dashboard.[19] These forecasts are not specific to each industry, but reflect how overall demand for roles relevant to the frontier industries might grow across the whole economy. This scenario is considered a lower bound, given that the frontier industries, by definition, are expected to have high growth potential (exceeding that of the rest of the economy).
- **Higher-growth:** This applies an average expected industry growth rate to 2035, based on a consensus across published literature and industry forecasts (see Table 6). These forecasts typically report expected revenue growth, and it is assumed that demand for technical roles scales in line with each industry's revenue trajectory. This therefore represents an upper bound, as demand for roles may not scale directly with revenue.

The two growth scenarios are then applied to the upper- and lower- bound estimated number of technical vacancies in 2025, providing an indicative forecast range of total vacancies for technical roles to 2035 for each frontier industry.

Table 6 Compound average growth rates in technical professional vacancies to 2035

Frontier industry	Lower-growth CAGR	Higher-growth CAGR
ACT	0.7%	5%
AI	1.1%	33%
Cyber security	0.7%	11%
Engineering biology	0.7%	17%
Quantum technologies	0.7%	25%
Semiconductors	0.7%	12%

Source: Frontier Economics analysis of Jobs and Skills Dashboard and consensus growth forecasts. See Annex B for further detail.

[19] The dashboard estimates are informed by the Skills Imperative 2035 forecasts, which model long-term occupational trends across the UK economy between 2023 and 2035.

7.2 Projected shortfall in the number of technical professionals to 2035

Table 7 reports the projected cumulative shortfalls in technical professionals to 2035 across the six frontier industries. The ranges reflect the significant uncertainty in the forecasts. Overall, each industry exhibits rising unmet demand over the period, albeit from different baselines and with varying growth trajectories. By 2035, the largest cumulative shortfalls are projected for AI and cyber security. ACT displays comparatively smaller deficits, though these remain significant relative to their baseline workforce sizes.

In the low-growth scenario, shortfalls in technical professionals are due to rise by a minimum of around 10 times in the quantum industry and around 13 times in the semiconductors industry by 2035. In the high-growth scenario, shortfalls in technical professionals are due to rise by a minimum of around 15 times in the ACT industry and around 65 times in the AI industry over the same time period.

Table 7 Estimated cumulative shortfall in technical professionals to 2035 in industry

Frontier industry	2025	2030	2035
ACT	0 – 100	100 – 700	300 – 1,500
AI	600	3,500 – 7,900	6,600 – 38,700
Cyber security	600 – 1,000	3,700 – 8,400	6,900 – 21,000
Engineering biology	300 – 600	2,000 – 5,800	3,700 – 17,000
Quantum technologies	200 – 500	1,000 – 5,500	1,900 – 20,700
Semiconductors	400 – 900	2,700 – 7,400	5,000 – 18,900

Source: *Frontier Economics*

Note: *The reported results are based on the low-growth, lower-bound scenario and the high-growth, upper-bound scenario. Numbers have been rounded to nearest 100.*

Currently, there is limited published evidence on shortages of technical professionals across the frontier industries to benchmark these forecasts against. Where they do exist, they are found to be consistent with the findings presented above. For example:

- **Cyber security:** DSIT's (2025) analysis estimates an overall workforce shortfall of approximately 3,800 workers in the UK cyber security industry in 2025. Applying the estimated technical professional share of 15–21% to this figure suggests a corresponding shortfall of around 570–930 roles in 2025. This aligns closely with the estimates derived in this analysis, which indicate a gap in technical professionals in the range of approximately 600–1,000 in 2025.

- **Semiconductors:** The DSIT (2025) Semiconductor Workforce Study projects a cumulative workforce shortfall of approximately 10,460 workers by 2030. Applying DSIT's estimate that around 69% of the semiconductor workforce are technical professionals suggests an equivalent cumulative shortfall of roughly 7,200 by 2030. This aligns closely with the upper-bound, high-growth-rate estimates of 7,400 technical professionals by 2030. Furthermore, DSIT's higher-growth scenario projects cumulative workforce deficits exceeding 20,000 by 2030 of total workforce which, using the 69% assumption, equates to 13,800 technical professionals, suggesting that even the upper-bound estimates in this analysis may be conservative.[20]

7.3 Qualitative insights into future skills shortages

Throughout the qualitative engagement, participants were asked whether and how they expected skills shortages to develop over the next 5 to 10 years. Although participants were not expected to quantify these trends, the majority confirmed that they expected skills shortages to grow, mirroring the quantitative findings presented in Section 7.2 above.

Turning to the nature of future skills shortages, stakeholders in most industries identified (i) practical and applied skills, and (ii) proactivity and innovative thinking as areas where shortages are likely to increase without further intervention. These are the same skills outlined in Chapter D1. AI was also raised as a cross-cutting theme across industries, with technologies becoming increasingly automated. For example, it was noted that:

- The ACT industry will likely rely on AI to play an increasing role in tuning models, robotics and security;
- The cyber security industry increasingly relies on AI for auto-detecting threats and auto-blocking activities; and
- The engineering biology industry will increasingly rely on AI to develop machine-learning models for solving biological and biotech problems.

Stakeholders reported that it will be necessary for technical professionals to be proficient in applying and validating AI tools and, in some cases, building and training them directly. Multiple participants expressed concerns that technical professionals were not yet sufficiently equipped with these skills, and that these shortages would grow without further intervention.

More generally, participants at the roundtable discussion emphasised that innovation and technological change is progressing faster than qualifications are able to adapt. In particular, in many industries, skills requirements change significantly by the time students have started

[20] These findings mirror broader international trends in semiconductor labour markets. Globally, forecasts suggest demand for 1 million additional semiconductor workers by 2030 (Deloitte, 2024). In Europe alone, the semiconductor industry is expected to experience a workforce shortfall of around 75,390 technical professionals by 2030, with the most acute gaps anticipated among hardware engineers and technicians (European Chips Skill Academy, 2024).

and completed their degrees. As a result, there is an ongoing challenge in ensuring that the future skills landscape is aligned with future skills requirements.

Possible solutions for bridging future skills shortages were discussed throughout the stakeholder interviews and roundtable discussion. Participants particularly emphasised that collaboration is needed between universities and industry to shape curricula in line with emerging needs, and that training and education should be continuous throughout the careers of technical professionals, rather than ending after university. Specific solutions participants suggested included:

- Implementing short, targeted courses aimed at new entrants into the industries as well as existing technicians;
- Supporting industry-led training through apprenticeships and/or industry-led modules; and
- Increasing support for SME's by providing access to affordable advanced computing resources, secure data spaces, experimental labs, and testbeds.

7.4 Summary of findings and identified gaps

Overall, the analysis above consistently indicates that, without a significant expansion in the pipeline of technical professionals, cumulative shortfalls will increase across all frontier industries by 2035. The industries expected to experience the largest absolute shortages of technical professionals are AI and cyber security.

The forecasts produced have been estimated using the best available evidence. However, they are subject to a number of assumptions and data limitations. For this reason, and in the absence of other forecasts for the majority of the frontier industries, the interim workshop was used to cross-check the assumptions made and final forecasts.

Throughout the qualitative engagement, participants were unable to confidently forecast future trends in the skills shortages experienced by the industries. However, shortages relating to the proficiency with handling AI tools, as well as the challenges of keeping up with emerging technologies and innovations, were consistently raised as key themes.

7.5 Policy recommendations

Based on the findings set out above, we make three policy recommendations relating to future skills shortages (FS) within the frontier industries (FS1 to FS3):

FS1 Periodic horizon-scanning should be undertaken to assess and quantify where technical skills shortages are likely to worsen or ease over time. Given the rapid pace of change in skills needs, an adaptable approach to policymaking in this area is likely to be essential.

FS2 Producing updated technical professional shortfall forecasts using more robust industry-specific data is advised. While all forecasts should be treated with a degree of caution, they are necessary to quantify the scale of intervention required. Forecasts should cover both academic and industry shortages.

FS3 Steps should be taken to ensure technical professionals are continuously trained in line with the emerging skill needs in each frontier industry. A particular focus should be on upskilling the workforce around the everyday use cases of AI, as well as the validation and appraisal of AI outputs. Providing opportunities for technical professionals to develop skills relating to proactivity and innovative thinking, and to learn practical and applied skills, is also key.

8 The role of universities and research institutes

HM Government's white paper (2025) on Post-16 Education and Skills stresses the vital role that UK higher education plays in supporting economic growth and building the country's skills base. It particularly draws on evidence from Skills England (2025d), which shows that priority occupations linked to the Industrial Strategy typically require qualifications at Level 4 or above. Despite this, across the six frontier industries, there is relatively limited industry-specific evidence on the contribution of universities and research institutes to supporting technical skills. There is even less evidence covering the current educational and professional pathways into technical roles in frontier industries, and the barriers technical professionals face when entering and progressing in each industry.

However, the available evidence on educational attainment provides a strong indication of the key role that universities and research institutes play in training the technical workforce. Based on the Jobs and Skills Dashboard (2024) data presented in Chapter 5, roles relevant to the frontier industries are consistently more highly educated than the economy-wide average. Between 63% and 73% of early-career workers across these industries enter via higher education routes, compared with just 40% across the wider economy. The qualitative engagement also confirmed that higher education is the primary route into each industry. This pattern reinforces the pivotal role of universities as the current primary gateway into frontier industries and highlights their likely continued importance in sustaining the future pipeline of technical skills.

More broadly, UK universities play an increasingly important role in addressing the national technical professional skills gap through a suite of linked initiatives, notably including the Technician Commitment, the TALENT Programme, and the UK ITSS. The Technician Commitment, launched in 2017 and now supported by over 100 universities and research institutes, provides the sector-wide framework for improving the visibility, recognition, career development, and sustainability of technical roles in higher education and research (Technician Commitment, 2025). Participating institutions commit to action plans that embed these principles within workforce strategies, ensuring that technical professionals are valued and supported.

Building on this foundation, the TALENT Programme (2020–2025), led by Midlands Innovation and funded by Research England, represented the largest coordinated investment in the UK's technical workforce. It sought to translate the goals of the Technician Commitment into large-scale action, supporting capacity-building, professional development, and cultural change across higher education and research institutions. The TALENT Commission (2024) made 16 national recommendations to strengthen technical career pathways, leadership, and workforce sustainability.

The UK ITSS was subsequently established in 2023 as a direct outcome of the TALENT Commission's recommendations, with £5.5 million in Research England funding to ensure the long-term sustainability of this work (UK ITSS, 2023). Hosted by the University of

Nottingham, it continues to advance the TALENT Programme's legacy through various initiatives embedding technical workforce planning and leadership development across the research and innovation system.

The UK ITSS's written evidence to Parliament (2025) further highlights universities' dual role as both educators and major employers of technical professionals, with more than 30 universities now hosting T Level industry placements and developing stronger apprenticeship and technical pathways in collaboration with employers (UK ITSS, 2025). Together, these initiatives demonstrate the increasing importance of institutional commitment to strengthening the UK's technical skills base and improving progression routes into and within technical careers.

Nevertheless, the Royal Society (2025) notes that there are significant challenges facing the higher education sector. Core science degree provision has declined over the past five years, and PhD enrolments - both domestic and international - have been broadly flat for a decade, despite doctoral students' central role in the research ecosystem. The report notes that strengthening the UK's talent pipeline with a broad mix of doctoral training across disciplines will be essential, alongside continued monitoring of trends; if numbers keep falling, the skills base of the research workforce will erode. The report also stresses the lack of individuals moving between academia, industry and government as a challenge.

The qualitative engagement also suggested that universities alone cannot bridge the gap between educational pathways and industry skills needs due to financial and practical limitations. For example, experimental environments (such as cleanrooms) are costly to maintain, and it is not always viable to allow undergraduate or master's students into facilities which contain high-value equipment or that require extensive health and safety training before entry. Therefore, university and industry collaboration will be required to re-align training programmes with industry needs.

The rest of this chapter summarises the industry-specific evidence on the role universities and research institutes play in the technical skills landscape for frontier industries and highlights identified evidence gaps.

8.1 Advanced connectivity technologies

There is limited evidence on the role of universities and research institutes in workforce development for ACT. As highlighted in Chapter 5, the Workforce Foresighting Hub (2025) identifies critical skills gaps within the telecoms workforce, particularly in relation to the deployment and optimisation of 5G infrastructure. The report highlights the need to formalise the integration of future-oriented occupational profiles (FOPs) into existing apprenticeship standards and training programmes, especially for new entrants. It also calls for the explicit incorporation of AI competencies into university-led 5G career pathways, ensuring that technical programmes evolve in line with emerging cross-disciplinary demands.

Several UK universities have taken steps to address these challenges by launching specialised degree programmes tailored to advanced connectivity. For example, the University of Essex now offers an MSc in 5G and Emerging Communication Systems, designed to equip graduates with practical and theoretical knowledge in the design, implementation, and deployment of 5G systems, with a strong emphasis on hands-on skills development (University of Essex, 2025). While such initiatives represent important progress, they remain limited in scope and scale. Drew (2025) cautions that these programmes alone are insufficient to meet the projected talent demands of the industry. Stakeholders also suggested that different departments at universities should collaborate to ensure students receive exposure to a wider range of training and expertise.

Complementing these findings, DSIT's (2023e) report on the UK Wireless Infrastructure Strategy acknowledges the importance of universities in the context of next-generation R&D. While the report primarily focuses on technological leadership and collaboration with international partners, it underscores the dual role of universities as both producers of R&D as well as trainers of the technical workforce. For example, in 2020–21, the UK produced the third-highest volume of research publications related to future telecoms, trailing only China and the United States. However, the translation of this research strength into scalable, industry-aligned training provision remains an open challenge.

Throughout the qualitative engagement, interviewees confirmed that apprenticeships were a less common pathway into technical roles in the ACT sector. Possible explanations included that (i) academic institutions are unable to guarantee jobs at the end of apprenticeships, thereby discouraging both the supply and demand of those schemes, and (ii) there has been a decline in domestic manufacturing, thereby reducing the number of domestic firms that can offer technical apprenticeships. However, given the breadth of expertise required by technical professionals in this industry, stakeholders suggested that higher education pathways may be better-suited for technical professionals to gain a wider range of cross-disciplinary skills.

Taken together, these sources suggest that, while universities have begun to respond to evolving skills demands in ACT, particularly through specialised degrees and research leadership, there is a need to strengthen their role in workforce development.

8.2 Artificial intelligence

Government policy recognises the importance of higher education institutions in addressing long-term AI skills needs. The DSIT AI Action Plan (2025b) calls for universities to significantly expand provision of AI training, both by increasing graduate numbers and embedding industry-relevant skills into courses. The Digital and Technologies Sector Skills Needs Assessment (2024) highlights a wider agenda, which involves attracting international AI professionals in the short term, expanding pathways into AI education, improving diversity, embedding lifelong learning, and supporting scholarships and conversion courses. In the longer term, the Department for Education (DfE), the Office for Students, DSIT and

Skills England are expected to coordinate efforts to increase AI graduate output and ensure training aligns with evolving industry needs. However, the current evidence presented in this report indicates a persistent mismatch between the supply of AI graduates and the capabilities sought by employers.

According to DSIT's AI Sector Study (2025c), stakeholders reported that the misalignment between industry demand and university provision is more acute in AI than in other advanced technology fields. Skills England (2025b) also highlight how slow curriculum responsiveness to emerging AI tools and sector-specific needs is a key structural barrier to AI upskilling. Frontier Economics (2025), drawing on AI-enabled analysis, examine current demand for AI skills in the UK labour market and assess the extent to which university graduates are positioned to meet this need. The report highlights a possible shortage of graduates with expertise in two particularly high-demand AI domains: natural language processing and cloud computing. Additionally, it showed that some skills appear to be widely taught in universities but rarely feature in job advertisements. This may indicate one of two dynamics. On the one hand, employers may assume that candidates already possess certain foundational AI capabilities (for example, statistical analysis) and therefore see no need to state them explicitly in job advertisements. On the other hand, universities may be placing disproportionate emphasis on areas that are less directly aligned with industry needs, which could contribute to a mismatch between graduate training and employer expectations.

Jaiswal et al. (2024) compares 30 UK university AI courses with 158 LinkedIn job postings using natural language and frequency-based analysis to identify gaps across twelve skill categories. The key findings include:

- **Strong alignment in core technical domains**: Universities and employers both prioritise programming and machine-learning, which together account for over 70% of the skill references in both curricula and job ads. These cover languages such as Python, Java and C++, and methods including supervised and unsupervised learning.
- **Significant shortages in data science, mathematics and statistics**: Demand for data-processing, analysis, and visualisation skills was found to be roughly twice the supply from universities, while the shortfall in mathematics and statistics exceeded 300%. Employers increasingly expect graduates to apply quantitative methods using tools such as R, Tableau and big data frameworks. These skills are rarely taught in depth at university level.
- **Over-emphasis on domain-specific knowledge**: Universities devote proportionally more attention to sectoral applications (for example, health and finance) than employers require. Industry tends to prioritise broad analytical capability and adaptability over narrow specialisation.

Stakeholders emphasised that industry-led apprenticeships could be a possible solution to overcome such gaps, providing students and trainees with direct exposure to industry data, technologies and analytical tasks. Representatives from universities and research institutes

highlighted that it is currently not feasible for higher education institutions to offer apprenticeships due to (i) insufficient resources to provide a formal rotation structure for apprentices, and (ii) the inability to guarantee apprentices longer-term roles at the end of their training. However, stakeholders suggested that models based around enhanced industry and university collaboration could partially address this challenge. For example, firms in industry could:

- Sponsor apprenticeships for university students (for example, through the Growth and Skills Levy); and
- Provide real-world datasets to CDTs to help simulate industry-style analytical tasks.

Overall, the existing evidence indicates that there remains a mismatch between the skills taught at universities and those required in industry. The outcome of efforts by DfE, the Office for Students, DSIT and Skills England to increase AI graduate output and ensure training aligns with industry needs will be key. Further collaboration between industry and universities should also be prioritised.

8.3 Cyber security

DSIT's (2025e) report on Cyber Security Skills in the UK labour market notes that, currently, 82 universities offer cyber security undergraduate courses, and 91 universities provide cyber security postgraduate courses in the UK. Evidence from the qualitative engagement also suggested that technical professionals often enter the cyber security industry from a wide range of non-specialist degrees, with the more specialised skills being learned on the job.

The DSIT (2025e) report also observes a steady increase in the share of postgraduate students from outside the UK and EU since 2018/19, when data was first collected, alongside a corresponding decline in the share of UK-domiciled students. While this trend reflects the strong international appeal of UK cyber security education, it may create long-term challenges for the domestic workforce pipeline, as many international graduates return overseas after completing their studies due to visa restrictions or employment opportunities abroad. Additionally, the unemployment rate among cyber security graduates remains notably higher than average at 9%, compared with 5% across all graduates (HESA, 2024). This persistent gap, consistent with findings from the previous two survey waves, suggests ongoing difficulties in transitioning from education into employment, with cyber security graduates struggling to meet employers' expectations (DSIT, 2025e).

The DSIT (2025e) report also notes that further education, particularly through apprenticeships, continues to serve as an increasingly important entry route into the cyber workforce. These pathways introduce learners to foundational concepts and can provide a bridge to more advanced study or professional qualifications. The report highlights that, alongside formal education routes, many employers value certifications from private training providers. The growth of alternative training models - such as cyber academies, intensive bootcamps, and accessible online learning platforms - has further expanded opportunities for

individuals to gain relevant experience and credentials. Interviewees throughout the qualitative engagement emphasised the value of both higher education and apprenticeship routes, and that both should be maintained as options.

Overall, qualitative evidence gathered through DSIT (2025e) interviews points to several barriers affecting entry-level recruitment. Employers and recruiters frequently noted that some graduates from cyber security degree programmes lack practical, up-to-date experience, as well as broader competencies such as communication and critical thinking. In several cases, participants contrasted graduates unfavourably with those entering through reskilling or upskilling pathways, who were often viewed as more work-ready. Respondents emphasised the need for stronger collaboration between industry and education providers to ensure that course content remains aligned with evolving employer needs and keeps pace with rapid technological change, particularly in areas influenced by artificial intelligence, which is expected to reshape many entry-level roles in the near future.

For cyber security, overcoming the identified barriers to recruitment, supporting the transition from education to employment, and exploring further education pathways (for example, through apprenticeships) are all likely to play a central role in overcoming the skills shortages seen in this industry.

8.4 Engineering biology

44 UK universities currently offer biotechnology bachelor and postgraduate degrees, which form key entry routes into this field (DSIT, 2023c). Universities are also drivers of entrepreneurship, with Cambridge and Oxford accounting for the highest number of engineering biology spinouts and company founders in the UK (Barclays, 2025). However, the Prime Minister's Council for Science and Technology (2023) highlights that there are still limited taught degrees focusing solely on engineering biology or biotechnology. This view was echoed throughout the qualitative engagement, with participants highlighting that most entrants to the industry come from generic degree backgrounds (such as molecular biology). As these are less specific to the engineering biology field, they do not equip students with the specialised skills required (such as design, engineering, and construction).

Postgraduate provision is particularly significant given the industry's need for advanced technical and interdisciplinary expertise. The UK has invested in several CDTs, such as the CDT in bio-design engineering and the CDT in engineering biology. These centres train students across biology, engineering, computation, and commercialisation. Building on this, UKRI has announced a new Doctoral Focal Award in engineering biology to support 33 studentships annually for three years from October 2026 (UKRI, 2025).

However, the evidence suggests higher education routes alone are insufficient. The Prime Minister's Council for Science and Technology (2023) has highlighted the complete absence of vocational courses (for example, BTECs, T-Levels) tailored to technical roles. To address this gap, the House of Commons (2025) report has urged Skills England to work with universities, industry, and Public Sector Research Establishments (PSREs) to expand

apprenticeships, including degree apprenticeships. UKRI has also been encouraged to fund master's-level conversion courses, enabling graduates from adjacent disciplines to gain the laboratory and industrial skills needed for careers in engineering biology (UKRI, 2025).

Across industries, respondents to a DSIT (2023c) study emphasised the value of apprenticeships and degree apprenticeships in addressing technical skills gaps not filled by the university graduate workforce. Drawing on evidence from academics, firms, and research institutes, a House of Lords (2025) report highlighted the urgent need to expand training for technical professionals. It also noted that, while apprenticeships, degree apprenticeships, and technical conversion courses are available, their current scale is insufficient to meet demand across the industry.

Throughout the qualitative engagement, interviewees highlighted the suitability of apprenticeships to equipping technical professionals with the practical skills required as the industry moves from its R&D-intensive phase towards biomanufacturing. However, given that it remains unclear which parts of the bioengineering industry will accelerate more rapidly than others, apprenticeship schemes would need to be carefully tailored towards the emerging industry trends as they develop.

In conclusion, both the National Vision for Engineering Biology and the House of Lords Science and Technology Committee stress the need to scale up doctoral training, diversify entry routes through apprenticeships and conversion courses, and revisit immigration policy to secure access to global talent (DSIT, 2023c; House of Lords Science and Technology Committee, 2025). Expanding apprenticeships, introducing flexible training at undergraduate and master's levels, and supporting technical careers have been identified in the literature and the qualitative engagement as vital to building the skills base required for the engineering biology industry.

8.5 Quantum technologies

Quantum technologies now feature on every UK physics bachelor's of science (BSc) course, and the UK has at least eight dedicated quantum master's programmes - the second-highest number globally, behind the US (DSIT, 2025k). Five UK universities rank in the global top thirty for the number of researchers active in quantum-related fields (DSIT, 2023b). The UK Quantum Skills Taskforce report (2025k) highlights the central contribution of universities across the full training pipeline, from undergraduate education through to doctoral training, research leadership, and technical support. However, the report also identifies misalignment between higher education provision and industry needs, capacity constraints within the academic workforce, and an acute shortage of technical staff supporting research.

The Quantum Skills Taskforce highlights key priority areas for strengthening the UK's quantum education and training pipeline, based on qualitative evidence gathered through workshops and consultations with more than 150 stakeholders from industry, academia, and national laboratories (DSIT, 2025k). These include:

- **Undergraduate provision**: Quantum technologies content is now a standard feature across all UK physics BSc courses. The Taskforce notes that quantum-specific modules and case studies should be integrated into relevant undergraduate programmes, particularly in engineering, computer science, and related disciplines. Mapping the quantum skills and knowledge required across these fields will enable universities to design targeted modules and raise awareness of career opportunities in the industry.
- **Master's programmes**: Qualitative engagement highlighted the need for MSc courses that are more tailored to industry requirements. Collaboration between universities and employers was highlighted as essential to ensure graduates develop the most in-demand skills, though it cautioned that such engagement must be structured to avoid duplication and minimise administrative burden. Accreditation was highlighted as critical for validating course quality and enabling recognition by professional bodies. While pathways exist for physics-based programmes, the lack of an agreed framework for accrediting quantum qualifications outside physics was identified as potentially affecting future continuing professional development courses.
- **Industry placements**: Work placements were identified as offering valuable hands-on experience to complement formal study. While existing schemes are often limited to physics students, a coordinated placement initiative, modelled on successful examples such as the Space Placements in Industry (SPIN) programme, could extend opportunities to engineering and computer science students, providing a broader talent pool with direct exposure to the industry.

Key themes arising from the qualitative engagement were around higher education courses being unable to equip technical professionals with sufficient applied skills. In particular, interviewees noted that technical professionals working in the quantum technologies industry require very specific skills to handle specialised technologies such as cryogenic refrigerators. These skills require years of practice that undergraduate and master's students do not have, as universities cannot afford to fund practical training on a widespread basis due to the costly nature of supporting cleanrooms and other experimental environments. In particular, participants reported reduced funding of cleanrooms across universities in recent years. Stakeholders also emphasised that, beyond the financial barriers, universities face practical barriers preventing them from offering widespread access to cleanrooms. These include the extensive training required to safely use cleanrooms and the high value of the equipment. Given the financial and practical barriers universities face, collaboration between industry and universities (for example, through industry placements) was reported as being crucial for increasing students' exposure to more applied environments to provide them with the required skills.

In conclusion, the current landscape demonstrates a strong academic foundation, with widespread integration of quantum content across university programmes. However, evidence from the Quantum Skills Taskforce (DSIT, 2025k) and qualitative engagement underscores that this academic strength must now be matched by closer alignment with industry needs, improved coordination across disciplines, enhanced technical capacity within universities themselves, and enhanced collaboration between industry and universities.

8.6 Semiconductors

DSIT's Semiconductor Workforce Study (2025l) notes that a significant proportion of new entrants to the UK's semiconductor workforce enter via higher education. It also indicates that over 80% of the workforce hold at least a bachelor's degree, with 14% possessing a PhD - significantly above the UK average. Nearly half of surveyed employers in the study reported that current university courses, particularly undergraduate programmes, do not adequately reflect the skills and knowledge required for semiconductor roles. This finding was reinforced by consultations that DSIT undertook with stakeholders, pointing to a disconnect between the theoretical focus of degree courses and their limited practical or semiconductor-specific content.

Similar themes emerged throughout the qualitative engagement, where participants reported that students receive limited exposure to cleanrooms or experimental environments due to the financial and practical barriers faced by universities (as described in Section 8.5 above). As a result, many students do not use cleanrooms until they begin a PhD. This means that a relatively large share of technical professionals hold PhDs, even though such roles do not formally require them. This highlights the misalignment between the applied skills required and the skillsets provided by undergraduate and master's degrees.

The same DSIT Semiconductor Workforce Study (2025l) notes that graduate outcomes data show that the University of Southampton, University of Strathclyde, University of Portsmouth, and Imperial College London produce the highest number of graduates who enter semiconductor-related employment within 12 months of graduation. This suggests that these institutions incorporate more semiconductor-relevant content within their curricula, and/or maintain stronger pathways into semiconductor industry employment. The report highlights that the pattern of graduate inflows does not mirror overall graduate output. While large engineering departments at universities such as the University of Manchester and the University of Sheffield produce high numbers of relevant graduates, they contribute less directly to the semiconductor workforce. This distinction points to opportunities to strengthen pathways and connections between these institutions and semiconductor employers.

Industry stakeholders from DSIT's engagement also emphasised the importance of alternative degree routes, particularly degree apprenticeships, which combine higher education study with structured on-the-job training (DSIT, 2025l). These are viewed as an effective means of equipping graduates with the practical, specialised skills required across design, manufacturing, and materials roles in the semiconductor industry. These views were corroborated by our own qualitative engagement. Participants also suggested that short, targeted courses in cleanrooms could play an important role, providing targeted opportunities for prospective technical professionals to improve their practical skills. Cambridge University's Royce Training course on practical cleanroom skills was cited as a successful example.

In summary, the limited information available for the semiconductors industry highlights the importance of higher education as a key route into the industry, although there appears to be a gap between the relevance of what is taught and the skills required by employers. Industry stakeholders have pointed to the potential role of routes outside of degrees as a path to meeting their requirements.

8.7 Summary of findings and identified gaps

Across the six frontier industries, several common themes emerge regarding the role of universities and research institutes in developing the technical workforce:

- **High reliance on higher education pathways:** All frontier industries draw heavily on degree-qualified entrants, particularly at the early-career stage. Doctoral and postgraduate education play a distinct role in quantum, engineering biology, and semiconductors, while AI and cyber security rely more heavily on undergraduate and master's-level provision.
- **Misalignment between university provision and employer needs:** In most industries, evidence points to gaps between the skills taught in universities and those required in practice. In AI and cyber security, the evidence suggests this misalignment might reflect rapid technological change and an insufficient emphasis on applied problem-solving. In semiconductors and quantum, emerging evidence suggests the gap may be rooted in limited practical training opportunities before entering the workforce.
- **Importance of industry collaboration and placements:** Stakeholder feedback across multiple industries emphasises the value of structured engagement between universities and employers to ensure training remains relevant. Work placements and degree apprenticeships are recognised as effective mechanisms for developing job-ready graduates, yet provision remains uneven and often concentrated in specific disciplines (for example, physics and engineering). This is also echoed by the Royal Society (2025), noting that the UK falls behind countries like Germany and the United States in promoting mobility between universities and businesses.
- **Need for diversified entry routes and technical professional pathways:** Several reports highlight the lack of vocational or hybrid qualifications bridging technical and higher education routes. Stakeholders also emphasised the value of short, targeted courses, aimed at developing specific skills.

Given each frontier industry relies so heavily on a labour force that is educated at universities, it is clear that universities will likely play a key role in closing the mismatch between the skills taught and employer needs, and meeting the expected shortage in technical roles identified in Chapter CS1. There remains, however, very little evidence as to how this scaling could be done in practice. This is particularly challenging given the lack of industry-specific information covering the current educational and professional pathways into technical roles specifically and the barriers technical professionals face when entering and progressing in each industry.

8.8 Policy recommendations

Based on the findings set out above, we make two policy recommendations relating to the role of universities and research institutes (RU) within the frontier industries (RU1 to RU2):

RU1 University curricula should be better aligned with industry needs. This includes providing, where possible, increased exposure to more practical and applied environments. Interventions should support collaboration between universities, CDTs and industry.

RU2 Alternative pathways for technical professionals should be investigated alongside higher education options. This could include leveraging T-Levels, V-Levels or apprenticeships funded through the Growth and Skills Levy.

9 Conclusion

This report has synthesised the available evidence related to the technical skills landscape across the UK's six frontier industries within the Digital and Technologies sector. The rapid evidence assessment and qualitative engagement demonstrate that the UK has clear strengths across the six frontier industries in the Digital and Technologies sector. There are, however, a number of challenges, many of these shared across industries. These are:

- **The six frontier industries vary significantly in their size and economic contribution.** Evidence on the economic contribution of the UK's frontier industries remains uneven, making it difficult to compare their true scale.
- **Gender diversity is a consistent and significant challenge.** In every frontier industry examined, men occupy the vast majority of relevant roles.
- **There are shortages of technical professionals and engineers.** Persistent deficits exist at multiple levels of the technical pipeline. These range from entry-level technical professionals supporting laboratory, manufacturing, and testing functions, to specialist engineers developing, integrating, and deploying advanced technologies. These shortages are often compounded by an ageing workforce in certain industries, limited visibility of technical career routes, and competition for talent across industries.
- **Technical professionals face barriers when entering and progressing through the frontier industries.** Cross-industry barriers exist in terms of (i) a lack of awareness of technical roles in frontier industries, and (ii) poor working conditions across universities and research institutes. These factors contribute to a reduced supply of prospective technical professionals.
- **Skills shortages are likely regionally imbalanced.** Public and private investment was perceived to be unequally distributed geographically, resulting in skill shortages being concentrated in certain parts of the UK.
- **Frontier industries face rapidly evolving skill requirements.** Technological change, such as the integration of AI and automation, is reshaping the technical competencies demanded in roles across all industries. The need for continual upskilling and reskilling was a recurring theme.
- **There is a misalignment between university provision and employer needs.** In most industries, evidence points to gaps between the skills taught in universities and those required in practice. In AI and cyber security, the evidence suggest this misalignment might reflect rapid technological change and an insufficient emphasis on applied problem-solving. In semiconductors and quantum, emerging evidence suggests the gap may be rooted in limited practical training opportunities before entering the workforce.
- **Industry collaboration and placements are essential.** Stakeholder feedback across multiple industries emphasises the value of structured engagement between universities and employers to ensure training remains relevant. Work placements and degree

apprenticeships are recognised as effective mechanisms for developing job-ready graduates, yet provision remains uneven and often concentrated in specific disciplines.

- **There is a need for diversified entry routes and technical professional pathways.** Several reports highlight the lack of vocational or hybrid qualifications bridging technical and higher education routes.
- **There are evidence gaps and inconsistent data reporting.** While an insightful evidence base already exists, there remain a number of evidence gaps when reporting the economic contribution, demographics and skills landscape of the frontier industries. In particular, the evidence appears relatively stronger in some industries than others; there appears to be uncertainty over industry definitions and use of differing methodologies and taxonomies in data reporting; there is limited data on diversity and inclusion; there is a lack of disaggregated data for technical roles, and there is limited quantitative information covering technical professional shortages or future skills requirements.

The Government has recognised this challenge, with skills now a high-priority policy area. In 2025 alone, this included the establishment of Skills England, the publication of the Post-16 Education and Skills White Paper, and the release of the UK Standard Skills Classification, among many other initiatives.

Our policy recommendations build on this work by identifying the most pressing evidence gaps and setting out how these could be addressed.[21] They are informed by detailed discussions with technical professionals, industry bodies, universities, research institutes and policymakers, alongside our assessment of the wider evidence base. Together, they provide a clear pathway to tackling the challenges identified and supporting the objectives of the UK Government's Modern Industrial Strategy.

[21] A consolidated list is provided in Annex C.

Annex A – SOC codes for technical professional forecasts

This annex presents a detailed breakdown of the Jobs and Skills Dashboard SOC codes identified as technical roles (lower bound and upper bound) for each of the frontier industries.

Table 8 ACT

Lower bound	Upper bound
■ Electrical and electronics technicians SOC2010 ■ Science, engineering and production technicians n.e.c. SOC2010	■ Electrical engineers SOC2020 ■ Electronics engineers SOC2020 ■ IT business analysts, architects and systems designers SOC2020 ■ Electrical and electronics technicians SOC2010 ■ Science, engineering and production technicians n.e.c. SOC2010

Source: Frontier Economics based on the Jobs and Skills Dashboard

Table 9 AI

Lower and upper bound
■ Engineering professionals n.e.c. SOC2020 ■ IT business analysts, architects and systems designers SOC2020 ■ IT quality and testing professionals SOC2020

Source: Frontier Economics based on the Jobs and Skills Dashboard

Note: For AI there is no lower bound or upper bound, given that none of the relevant occupation roles explicitly mention "technicians"

Table 10 Cyber security

Lower bound	Upper bound
■ IT operations technicians SOC2020 ■ IT user support technicians SOC2020 ■ Database administrators and web content technicians SOC2020	■ IT business analysts, architects and systems designers SOC2020 ■ IT quality and testing professionals SOC2020 ■ Information technology trainers SOC2020

Lower bound	Upper bound
	■ IT operations technicians SOC2020 ■ IT user support technicians SOC2020 ■ Database administrators and web content technicians SOC2020

Source: Frontier Economics based on the Jobs and Skills Dashboard

Table 11 Engineering biology

Lower bound	Upper bound
■ Laboratory technicians SOC2020 ■ Quality assurance technicians SOC2020 ■ Planning, process and production technicians SOC2020 ■ Science, engineering and production technicians n.e.c. SOC2020	■ Chemical scientists SOC2020 ■ Biological scientists SOC2020 ■ Biochemists and biomedical scientists SOC2020 ■ Production and process engineers SOC2020 ■ Engineering professionals n.e.c. SOC2020 ■ Quality control and planning engineers SOC2020 ■ Laboratory technicians SOC2020 ■ Quality assurance technicians SOC2020 ■ Planning, process and production technicians SOC2020 ■ Science, engineering and production technicians n.e.c. SOC2020

Source: Frontier Economics based on the Jobs and Skills Dashboard

Table 12 Quantum

Lower bound	Upper bound
■ Laboratory technicians SOC2020 ■ Electrical and electronics technicians SOC2020	■ Physical scientists SOC2020 ■ Electrical engineers SOC2020 ■ Electronics engineers SOC2020 ■ Production and process engineers SOC2020 ■ Engineering project managers and project engineers SOC2020

Lower bound	Upper bound
	■ IT business analysts, architects and systems designers SOC2020 ■ Laboratory technicians SOC2020 ■ Electrical and electronics technicians SOC2020

Source: Frontier Economics based on the Jobs and Skills Dashboard

Table 13 Semiconductors

Lower bound	Upper bound
■ Laboratory technicians SOC2020 ■ Engineering technicians SOC2020 ■ Planning, process and production technicians SOC2020 ■ Science, engineering and production technicians n.e.c. SOC2020	■ Electronics engineers SOC2020 ■ Production and process engineers SOC2020 ■ Engineering professionals n.e.c. SOC2020 ■ Laboratory technicians SOC2020 ■ Engineering technicians SOC2020 ■ Planning, process and production technicians SOC2020 ■ Science, engineering and production technicians n.e.c. SOC2020

Source: Frontier Economics based on the Jobs and Skills Dashboard

Annex B – High-growth scenario evidence for technical professional forecasts

This annex presents the evidence underpinning the high-growth scenario for the gap projections for technical professionals. The compound average growth rate (CAGR) for each industry involved taking an average of the industry-specific market studies on revenue growth, summarised in Table 14 below.

Table 14 Average CAGR

Frontier industries	Evidence	Average CAGR
ACT	■ Grand View Horizons (2025) forecasts that the UK telecom services market will expand at a compound annual growth rate (CAGR) of 6.7% between 2025 and 2030. ■ Imarc's UK Telecommunications Market Report projects a 5% CAGR over the same period. ■ Mordor Intelligence (2025) estimates a 3.41% CAGR, with the UK market expected to grow from USD 30.54 billion in 2025 to USD 36.12 billion by 2030.	≈ 5%
AI	■ According to the US International Trade Administration, the UK AI market - valued at over $21 billion in 2023 - is expected to exceed $1 trillion by 2035, implying an CAGR of around 38%. ■ Grand Horizon's (2025) UK Artificial Intelligence Market Size & Outlook projects an average CAGR of 29% between 2025 and 2033. ■ IMARC's (2025) UK Artificial Intelligence Market Report estimates a CAGR of 22.6% over the same period.	≈ 33%
Cyber security	■ Grand Horizon (2025), UK Cyber Security Market Size & Outlook projects a 12.8% CAGR (2025–2030). ■ The Data City (2025) indicates ≈ 11% average annual company growth.	≈ 11%

Frontier industries	Evidence	Average CAGR
	■ Mordor (2025) UK Cyber Security Market Report estimates an 11% CAGR (2025–2030). ■ Spherical Insights (2025) estimates 11% CAGR.	
Engineering biology	■ Grand View Research (2025), UK Synthetic Biology Market Size projects 18% growth (2025–2030). ■ IMARC (2025), UK Synthetic Biology Market Size projects 15% growth (2025–2033).	≈ 17%
Quantum technologies	■ Grand View Research (2025), UK Quantum Computing Market Size & Outlook projects a 14% CAGR (2025–2030). ■ IMARC (2025), UK Quantum Computing Market Size estimates a 33% CAGR. ■ Market Research Future (2025) forecasts ≈ 27% CAGR (2025–2035).	≈ 25%
Semiconductors	■ The DSIT (2025) Semiconductor Workforce Study found that revenue data for 40 dedicated UK semiconductor firms reflected an average ten-year annual growth rate of around 8%. ■ A DSIT (2025) press release announcing a £10 million fund to support UK semiconductor businesses reported an expected 75% increase in industry size between 2025 and 2030, equivalent to a CAGR of 11.8%. ■ Grand Horizon (2025) forecast a 15.7% CAGR in revenue for the UK semiconductor memory market between 2024 and 2030.	≈ 12%

Source: Frontier Economics

Annex C – Consolidated policy recommendations

Table 15 consolidates the policy recommendations provided throughout this report.

Table 15 Policy recommendations

Topic	#	Recommendation
Economic Contribution	EC1	Standardise, where possible, the approach to data collection, modelling assumptions, taxonomies, and timeframes across studies. This could include developing new or adapted SIC and SOC classifications (or potentially hybrid options). This will minimise ambiguity and enable more accurate comparisons across industries.
	EC2	Gather data to provide detailed breakdowns of the number of technical roles and their type in each industry. This would enable more detailed analysis of skills needs in these industries.
	EC3	Provide a regional breakdown of economic statistics (revenue, number of firms, GVA, number of employees). This breakdown should be at the ITL1 level as a minimum, or in line with the Skills England's (2025a) specified areas in their Local Skills Improvement Plans.[22,23] This will help identify and track industry clusters as they develop over time.
Demographics of the workforce	D1	Develop a consistent dataset providing comparable demographic data across technical roles in frontier industries over time. This should include gender, but possibly other characteristics such as sexual orientation, ethnicity, age, disability, neurodiversity, and socioeconomic background. Enhanced workforce demographic data will improve the ability to track trends in the technical workforce, informing policy interventions across skills planning and research agendas.
	D2	Steps should be taken to further explore the causes of gender imbalances and possible solutions. In particular, interventions should be aimed at younger students, after which it likely becomes more difficult to tackle these imbalances.
Current skills landscape	CS1	Detailed and consistent information quantifying technical skills shortages and vacancies should be collected to enable policy responses to be effectively targeted. The data should be sufficiently granular to identify the specific occupations, qualification levels, skills and technical functions most affected. While the available evidence points to persistent skills gaps, their precise scale remains unclear.
	CS2	A robust, data-driven mapping of current and emerging technical skills should be completed. While the qualitative engagement points to themes such as a lack of practical and applied skills, proactivity, innovative thinking, and proficiency with

[22] ITL1 refers to the highest level of major socioeconomic regional breakdown, consisting of nine English regions (like London, South East, etc.) plus Scotland, Wales, and Northern Ireland.

[23] Skills England identify 'specified areas' for local skills improvement within the North East, North West, Yorkshire and the Humber, East Midlands, West Midlands, East, Greater London, South East and South West. For example, Cheshire and Warrington, Cumbria, Greater Manchester, Lancashire and the Liverpool City Region are specified areas in the North West.

Topic	#	Recommendation
		handling AI tools (which may be early places to focus), gaining a comprehensive view across industry is key.
	CS3	A systematic analysis of retirement risks, succession planning, and supply of prospective technical professionals should be conducted for each frontier industry. By understanding workforce dynamics and future replacement needs, government can then proactively address potential challenges before they arise.
	CS4	Steps should be taken to improve the pipeline of skills and awareness of technical routes early, before children start to specialise. This may help break down barriers and improve the supply of prospective technical professionals.
	CS5	The working conditions of technical professionals should be improved. This includes potentially supporting improved pay, progression and job security of technical professionals in the higher education sector in particular.
	CS6	Ensure there is a level playing field in funding and support across regions. The qualitative engagement indicated that developing regional skill clusters and talent pipelines, and supporting SME ecosystems beyond the Golden Triangle could help address this.
	CS7	Align educational pathways more closely with industry skill needs. This includes a stronger focus on developing students' practical skills, innovative thinking, and proficiency with handling AI tools.
Future shortages of technical professionals	FS1	Periodic horizon-scanning should be undertaken to assess and quantify where technical skills shortages are likely to worsen or ease over time. Given the rapid pace of change in skills needs, an adaptable approach to policymaking in this area is likely to be essential.
	FS2	Producing updated technical professional shortfall forecasts using more robust industry-specific data is advised. While all forecasts should be treated with a degree of caution, they are necessary to quantify the scale of intervention required. Forecasts should cover both academic and industry shortages.
	FS3	Steps should be taken to ensure technical professionals are continuously trained in line with the emerging skill needs in each frontier industry. A particular focus should be on upskilling the workforce around the everyday use cases of AI, as well as the validation and appraisal of AI outputs. Providing opportunities for technical professionals to develop skills relating to proactivity and innovative thinking, and to learn practical and applied skills, is also key.
The role of universities and research institutes	RU1	University curricula should be better aligned with industry needs. This includes providing, where possible, increased exposure to more practical and applied environments. Interventions should support collaboration between universities, CDTs and industry.
	RU2	Alternative pathways for technical professionals should be investigated alongside higher education options. This could include leveraging T-Levels, V-Levels or apprenticeships funded through the Growth and Skills Levy.

Source: Frontier Economics

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