Science 2040

Interim report

THE ROYAL SOCIETY

Science 2040: Interim report
Issued: May 2025 DES9206_1
ISBN: 978-1-78252-781-7

This report can be viewed online at:
royalsociety.org/science2040

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Executive summary

Science 2040: A vision for the future

Science has long been at the heart of human progress, driving economies, improving our health and wellbeing, and deepening our understanding of the universe. The UK has built a reputation as a global leader in scientific research, but sustaining and strengthening this position requires long-term vision, strategic investment, and policy frameworks that foster and enable innovation. Science 2040 sets out a vision for a science and innovation ecosystem that is more resilient, more responsive to society's needs, and better aligned with the challenges and opportunities of the decades ahead.

Science enriches lives in profound ways. Beyond its substantial and varied economic contributions, it informs decision-making, inspires curiosity, and equips us to tackle emerging challenges – from pandemics and climate change to technological transformation. The increased spread of misinformation has reinforced the need to uphold the value of science, and clearly communicate the transparency and integrity that make science trustworthy. A robust and trustworthy science system, in which scientific inquiry and application are able to thrive, is essential to national security, societal resilience, and long-term prosperity.

The UK science landscape is at a critical juncture. Capriciousness in politics has led to unpredictable and short-term funding cycles that undermine research stability and create an uncertain investment environment. Gaps in key skills and infrastructure hinder the country's ability to translate discovery into application. The fragmented nature of vocational and higher education pathways limits the flow of skilled talent into research institutions and industry. At the same time, restrictive immigration policies risk deterring global expertise, and barriers to interdisciplinary collaboration slow progress on complex challenges. Increased politicisation of research in other parts of the world is creating new uncertainties that not only threaten academic freedom but also disrupt the international networks and collaborations that science depends on.

Yet the UK has an opportunity to strengthen its scientific future, even in the face of global geopolitical shifts reshaping the context in which research and innovation take place. By fostering partnerships between industry, academia, and government, investing in world-class research facilities, and creating a more diverse and inclusive research workforce, the UK can reinforce its position as a hub of discovery and innovation. A more agile and sustainable funding model will provide the foundation for breakthroughs that drive long-term economic growth and improve lives across society.

Purpose of this interim report

This report brings together the first phase of the Science 2040 programme, focused on the value of science to society and current strengths and weaknesses of the UK's science and innovation system in delivering this. It draws insights from those working across research, industry and government, as well as on historical analysis and international comparisons. It reflects a shared recognition that meeting the ambitions of the coming decades will require a more strategic, coherent, and enduring approach to science policy.

It seeks to make a general case for a long-term vision of science for the UK and what the parameters of this should be, and identifies the greatest long-term challenges this needs to address.

Guiding principles for the science system of 2040

The future is uncertain. The UK will need a science system that is agile and responsive to change in order to empower scientists and investors to pursue and support the ambitious research that will lead to the next generation of breakthroughs, and to act responsively to emerging opportunities or emergencies.

Facing a tumultuous world, government will need to act to reduce uncertainty where it can rather than adding to it. This means ensuring a clear, stable and predictable policy environment.

Whatever the world of 2040 looks like the following principles need to be baked into UK science policy to ensure it remains able to deliver for society:

1. **Excellence**
   Maintain the highest standards in research, innovation and the application of these to secure the UK's global standing.
2. **Research integrity**
   Ensure transparency, reproducibility, and ethical rigour in scientific practice.
3. **Institutional diversity**
   Develop a more diverse research system that fosters innovation, enhances resilience, drives competition, and enables collaboration.
4. **Predictability in policymaking**
   Create stable policy conditions in which investors feel confident to invest and gives the stability within which scientists can take risks.
5. **Interdisciplinarity**
   Break down silos between fields, enabling collaboration on complex challenges.
6. **Coherence**
   Ensure alignment across sectors and policy-making bodies to enable the free flow of ideas and talent across the research and innovation ecosystem.
7. **Enabling regulation and administration**
   Build streamlined, efficient, and supportive frameworks that facilitate research activities while minimising unnecessary bureaucratic burdens.
8. **Independence of research**
   Ensure those who understand the research best are empowered to take the decisions over research activities.
9. **A system inclusive of all**
   Build the talent pool so the research and innovation ecosystem can benefit from a diverse range of talent and expertise who are empowered to operate at their full potential.
10. **International collaboration**
    Strengthen international ties, making the UK a magnet for talent and collaboration.

Science is the foundation of a thriving society. The UK's continued success depends on sustained investment, a dynamic research environment, and an unwavering commitment to excellence in every aspect of the scientific endeavour.

Recommendations

RECOMMENDATION 1

Establish a long-term science strategy to end the damaging cycle of short-termism and stop-start investment in science

By 2040, the UK will be seeing the long-term benefits of a resilient, forward-looking science strategy – one that has provided policy clarity in the face of global volatility and enabled sustained real-terms growth in research and development (R&D) investment for over a decade. Cross-party support will have been central to its continuity and impact. To achieve this by 2040, government needs to:

- Implement a 10-year investment framework, reviewed every five years, ensuring science funding keeps pace with inflation, global developments and economic opportunities.
- Ensure greater flexibility in the year-on-year budgeting requirements for funders within these longer-term funding envelopes to support more effective and efficient investment for the whole system.
- Align science policy with long-term industrial, skills, and infrastructure strategies to create a coherent national approach to research and innovation.
- Develop an internationally focused science strategy to attract global R&D investment and establish measurable targets for skills development and infrastructure.
- Develop metrics that capture the full value of investment in R&D to the economy. These must account for the ‘non-rival’ and ‘non-excludable’ nature of scientific knowledge, meaning many people can benefit and build on any single scientific advancement; and the inherent uncertainty and variability on the journey from cutting-edge research to economic impact.

RECOMMENDATION 2

Strengthen the skills and education ecosystem to deliver a more numerate and scientifically literate population

By 2040, a joined-up, strategic approach to skills and education policy will have been fully embedded across the UK, aligning efforts across all levels of government, from central departments to devolved administrations and combined authorities. To achieve this by 2040 requires action imminently to:

- Ensure a broad curriculum that engages students in science, mathematics, and data skills to age 18, with hands-on, practical learning.
- Ensure the public have access to trustworthy and high-quality information about science, the natural world and emerging technologies, as a counter to misinformation.
- Support both higher and further education sectors, ensuring clear technical and vocational pathways and closer collaboration with industry and training providers.
- Support talented researchers to reach their full potential by providing appropriate training opportunities and rethinking the career pyramid.
- Incentivise private sector involvement in workforce training, upskilling, and lifelong learning to keep pace with new technologies and methodologies.
- Reform immigration policy to make it easier for world-class scientific talent – both established researchers and those early in their careers – to work and settle in the UK, removing barriers such as high upfront visa and health surcharge costs.

RECOMMENDATION 3

Foster a diverse research and innovation system to ensure system-wide adaptability and resilience

By 2040, a wider variety of institutions and funding sources must be supported to foster adaptability, resilience, and breakthrough discoveries. To deliver this, government should:

- Maintain a balanced portfolio of discovery, applied and mission-driven research to ensure long-term scientific progress.
- Strengthen the UK's role as a leader in interdisciplinary and collaborative research, including integrating AI, materials science, and biotechnology to address societal challenges.
- Address gaps in maintaining foundational scientific knowledge that is crucial to national security and future technological development.
- Promote competitive funding mechanisms to sustain research excellence and encourage bold, high-risk innovation.

RECOMMENDATION 4

Make the UK a leading nation in which to innovate and translate knowledge

By 2040, the UK must have removed barriers to innovation and enhanced pathways from research to commercial and societal impact. To achieve this:

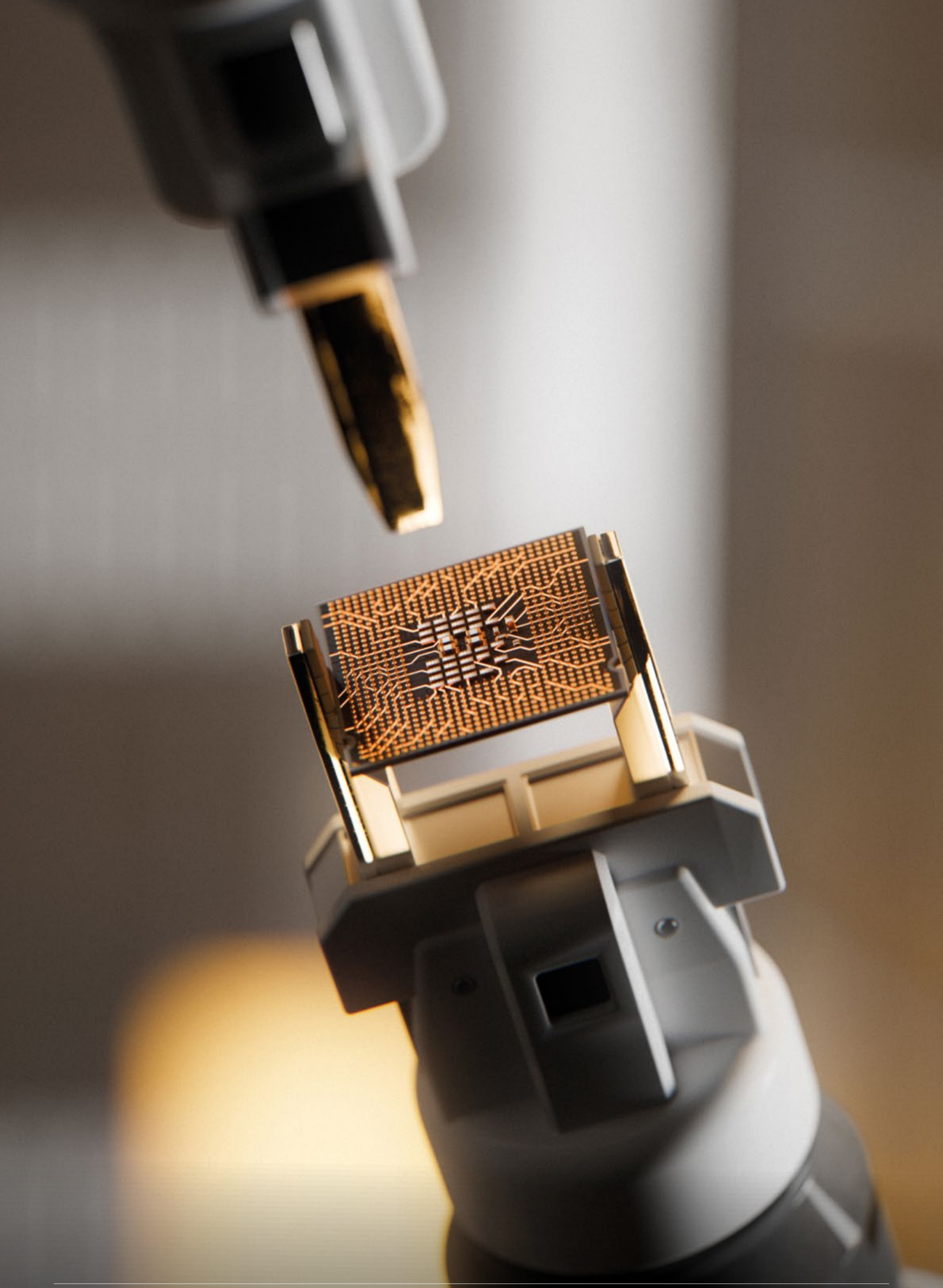
- Review and optimise translational pathways, ensuring institutions are structured to maximise knowledge commercialisation. Act to ensure translation institutions complement other parts of the system and remove needless barriers to translation activity for other publicly funded research institutions where such functions may be important while not the sole focus.
- Create an enabling regulatory system to incentivise innovation and ensure UK-generated research translates into economic value captured in the UK. Remove constraints that inhibit innovation, ensuring policies enable rather than restrict scientific progress and application.
- Tackle disparities in access to innovation opportunities, ensuring diversity in participation across geography, gender, and ethnicity.
- Improve the overall investment environment by reducing policy uncertainty.

RECOMMENDATION 5

Reimagine science careers and organisational structures

By 2040, science careers and research organisations should be restructured to support a dynamic and inclusive research environment. Making this a reality requires government to:

- Adapt doctoral training models to better align with the needs of both academia and fast-moving industry sectors.
- Develop new science training pathways for data- and technology-intensive fields, equipping people with interdisciplinary skills.
- Actively incentivise intersectoral mobility through funding mechanisms, employer initiatives, and in recognition and assessment frameworks.



Part one

Building a long-term vision for science

Left

What is science for?

Introduction

Science is one of humanity's most transformative endeavours, shaping the way we understand and interact with the world around us. It drives innovation, improves quality of life and equips society to tackle some of the most pressing global challenges. From life-saving breakthroughs in medicine to the technologies that connect billions of people, science enriches every aspect of human existence. Beyond its tangible outputs, science contributes cultural value by fostering critical thinking, curiosity and creativity.

The value of science goes far beyond economic growth and technological advancement. Scientific thinking equips individuals with the tools to approach complex problems systematically and make evidence-based decisions, a skill set increasingly vital in an era of misinformation. Scientific thinking underpins the resilience of society, enabling us to adapt to emerging challenges, whether they stem from health crises, climate change or national security threats. As this section explores, the cultural, intellectual and practical significance of science shapes not only the economy but also the very fabric of society.

The role of science in the economy

Scientific research, and the innovations that build on it, have transformed the world. Some of the outcomes are highly visible – for example new treatments for disease or new consumer electronic devices[1]. Others are less visible but provide the infrastructure for the modern economy, such as the network of fibre optic cables and associated optoelectronics on which the internet runs.

Investing in skills and scientific capabilities today lays the foundation for the UK's future prosperity and international competitiveness – improving people's lives and creating the jobs of the future. Science, technology and computer/machinery manufacturing contribute at least £164.1 billion (6.9%) in UK GVA[2]. The sector currently employs just under 3 million people, with one of the largest employment growth rates in the last decade[3].

While the focus is often on visible and direct cutting-edge technologies that emerge from scientific research and development (R&D), these represent only a slice of the economic value that science contributes. The impact on the economy of scientific activity is more pervasive and foundational. As well as impacting sectors traditionally associated with science such as the life sciences, telecommunications and automotive industries, science and technology have also impacted wider sectors such as the creative industries and financial services.

1 This section summarises the findings of the Science 2040 policy briefing: Science and the Economy (2024). Available at: https://royalsociety.org/news-resources/publications/2024/science-and-the-economy/ (accessed 11 March 2025)

2 Office for National Statistics (2024). GDP output approach: Low-level aggregates, 2024. Available at: https://www.ons.gov.uk/economy/grossdomesticproductgdp/datasets/ukgdpolowlevelaggregates (accessed 14 March 2025)

3 Office for National Statistics (2024). EMP13: Employment by industry, Available at: https://www.ons.gov.uk/employmentandlabourmarket/peopleinwork/employmentandemployeetypes/datasets/employmentbyindustryemp13 (accessed 14 March 2025)

In the creative industries – a sector estimated to have contributed £124.6 billion of GVA to the UK economy in 2022 – advances in technology have impacted areas such as gaming and film, leading to the creation of innovative new products, experiences and services[4]. Technology has also transformed the financial services sector with technologies such as blockchain, big data analytics and artificial intelligence (AI).

While the economy is founded on the products of scientific research, the direct economic impact is underestimated. Quantitative studies often focus on private rates of return on investment in research, with different authors producing estimates of anywhere up to 231%. These studies do not, however, capture the whole value created by the science system because of the amount of time it can take before a piece of research can be economically exploited; the 'non-rival' and 'non-excludable' nature of scientific knowledge, meaning many people can benefit and build on any single scientific advancement; and the inherent uncertainty and variability on the journey from cutting-edge research to economic impact.

Rates of return studies therefore capture a portion of the value generated, but only a small slice. The total contribution of science to the economy is much larger and can be understood through four interconnected paths to impact:

1. **New knowledge and ideas**
   Scientific research produces specific bodies of knowledge and process that can be applied for economic benefit.

2. **Innovation and productivity**
   The application of bodies of knowledge and process spills over into innovation and productivity gains.

3. **Skilled people and jobs**
   Scientific R&D has a significant impact on human capital, through education and training and the generation of new types of jobs. This enables knowledge diffusion across the country and the economy.

4. **Wider economic impacts which are not directly monetised**
   Science generates important benefits that enable other economic activity, from improved public health to environmental protection and national security.

4 Council for Science and Technology (2023) Harnessing Research and Development in the UK Creative Industries. Available at: https://www.gov.uk/government/publications/harnessing-research-and-development-in-the-uk-creative-industries (accessed 11 March 2025)

Basic research is critical to applied development

Basic research is critical for applied development. There is a close relationship between the development of the two that forms a virtuous circle, as often applied development reveals further basic science challenges. Basic research benefits the economy over long timescales and spreads more widely than applied knowledge, transforming the economy in ways that are impossible to predict. The rapid production of vaccines was underpinned by years of accumulated research on mRNA and coronaviruses. The origins of polymerase chain reaction (PCR) testing – another significant intervention during the pandemic – can be traced back to the chance discovery of a micro-organism *Thermus aquaticus* in the 1960s. The modern computer and the internet, which have become central to everything in the global economy, owe their existence to foundational investigations in electromagnetism and pure mathematics going back centuries.

While the international circulation of scientists and ideas is important, there remains a strong economic rationale for the UK to maintain its historic strength in discovery science rather than simply increasing its reliance on basic research undertaken elsewhere ('free-riding'). The application of discoveries usually requires sophisticated understanding and skills developed in the research sector. The ability to work with world-leading discovery scientists is one of the factors that leads R&D intensive companies to locate and remain in certain areas over others[5].

Building capacity for this type of discovery research – including the people, institutions and facilities it requires – is also key to allowing for rapid redeployment when needed, as demonstrated in the drive to develop a vaccine for COVID-19 at pace. Effectively accessing, interpreting and using cutting-edge science from elsewhere is also heavily dependent on having domestic capacity for discovery research.

Productivity

More sophisticated metrics are needed for assessing the economic value of intangible assets, such as scientific knowledge and processes, where much of the value is found in spillover effects rather than direct rates of return. This will only become more important as further 'platform' or 'general purpose' technologies come online and transform the economy.

Some new technologies have a particularly powerful effect on economic growth, because they can be used in many different sectors – they are 'general purpose technologies'. These pose a particular challenge in assessing value, as metrics such as Total Factor Productivity struggle to account for the behaviour changes such innovations lead to. A computer, for example, can be used in many different downstream and upstream sectors to produce many different types of goods and services. General purpose technologies can also improve the innovation process in the upstream sector. For example, machine learning and AI hold out the promise of accelerating the processes of drug and materials discovery – this might be regarded as an innovation in the process of innovation. Thus, such general-purpose technologies have the potential to raise productivity very significantly. This is not only because they're being used in lots of sectors, but they are improving the process of innovation in the upstream sector.

5 For a set of case studies illustrating this, see Royal Society (2024). Science and the Economy. Available at: https://royalsociety.org/news-resources/publications/2024/science-and-the-economy/ (accessed 11 March 2025).

Technological progress, which encompasses more than just making existing products cheaper, involves the introduction of entirely new product types that can fundamentally change consumption patterns (eg generating a previously non-existent demand). This then likely leads to enhancements in consumer welfare in ways that are not easily quantified by traditional productivity metrics. Rather than just affecting individual sectors of the economy, science has historically been radically transformative across it. The shape of the economy of 2040 will be intrinsically interlinked with the process of science.

Metrics

The UK must develop more sophisticated metrics to assess the full value of R&D. Current methods often underestimate the spillover benefits of scientific discovery, such as cross-sector innovation, productivity gains and societal impact. A comprehensive framework should account for both direct and indirect returns, capturing the long-term economic, social and strategic advantages of research. Other nations, such as Germany, integrate broad-based impact assessments into funding decisions, ensuring continued investment. By improving measurement tools, the UK can demonstrate the true value of R&D, strengthening the case for sustained public and private sector support.

Cultural value of science

There are many examples where scientific research and the innovations that build on that research have had significant and transformative impacts on society and the economy[6]. Whilst the economic benefits of science can be hard to quantify, many are in fact highly visible in terms of innovative technologies, products and processes. What is harder to quantify are the less tangible benefits on society of science and scientific thinking.

Beyond the knowledge and impact generated, science has the ability to inspire younger and older generations. In schools, practical science experiments and science lessons help develop the curiosity and creativity of students. More broadly, institutions such as the BBC have played a significant role in promoting the cultural value of science. The BBC has a long history of broadcasting science programmes on both radio and television, with prominent scientists such as Sir David Attenborough FRS and Professor Brian Cox FRS inspiring people of all ages through their demonstration and promotion of science and its broadcasting to wide audiences.

Science shapes how individuals relate to the natural world. It stimulates curiosity and provides cultural and intellectual enrichment. Participation in activities such as visiting science-related exhibitions can positively influence people's engagement with science[7]. The UK has several prominent cultural institutions dedicated to science and natural history, and these play a vital role in providing rich learning experiences to inspire young people and adults[8].

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6 Royal Society (2024). Science and the Economy. Available at: https://royalsociety.org/news-resources/publications/2024/science-and-the-economy/ (accessed 11 March 2025)

7 Science Museum Group (2020). Engaging all audiences with science. Available at: https://learning.sciencemuseumgroup.org.uk/wp-content/uploads/2020/04/science-museum-group-engaging-all-audiences-with-science.pdf (accessed 11 March 2025)

8 Museums and Heritage (2013). Education & Leaning through Science Museums. Available at: https://museumsandheritage.com/advisor/posts/education-learning-through-science-museums/ (accessed 11 March 2025)

Engaging with science enables individuals to build critical thinking and problem-solving skills, providing them with the capacity to question assumptions, engage with data and reach evidence-based conclusions. These skills provide individuals a way in which to systematically tackle problems.

Engaging with science also encourages individuals to build an objective and impartial view of the evidence. The pursuit of scientific research emphasises the need for objectivity and a data-driven approach without personal bias. Testing assumptions with data and reaching conclusions that are in alignment with the available evidence is critical to the scientific endeavour. Furthermore, scientific thinking requires individuals to be open-minded and adaptable to new beliefs in light of changing evidence.

Educating individuals in the values of objectivity and open mindedness is important to society, particularly as online platforms and digital technologies continue to transform the way people consume, produce and disseminate information[9]. On the one hand, the online information environment has democratised access to knowledge, shifting away from 'gatekept' information. On the other hand, it has also resulted in an environment which involves heightened competition for information, with concerns that the environment is becoming more fragmented and polarised[10, 11, 12]. The resulting misinformation and disinformation can lead to individuals mistrusting evidence[13].

Developing numeracy and scientific literacy is foundational to ensuring society is resilient to misinformation and disinformation. Building familiarity with and accessibility to science and scientific process into the education system are essential[14], as are lifelong literacy and education initiatives which can equip people with the skills to effectively evaluate online content[15].

9 Royal Society (2022). The online information environment. Available at: https://royalsociety.org/news-resources/projects/online-information-environment/ (accessed 11 March 2025)

10 International Science Council (n.d.). The public value of science. Available at: https://council.science/our-work/3-2-the-public-value-of-science/ (accessed 11 March 2025)

11 Kubin, E., & von Sikorski, C. (2021). The role of (social) media in political polarization: a systematic review. Annals of the International Communication Association, 45(3), 188–206. https://doi.org/10.1080/23808985.2021.1976070 (accessed 11 March 2025)

12 Gidron, N. Adams, J and Horne, W. (2019) Toward a Comparative Research Agenda on Affective Polarization in Mass Publics (2019). APSA Comparative Politics Newsletter. 29:30-36., Available at: https://ssrn.com/abstract=3391062 (accessed 11 March 2025)

13 Vosoughi S., Roy D, and Aral S. (2018). The spread of true and false news online. Science, 359 (6380) 1146-1151. Available at: https://www.science.org/doi/10.1126/science.aap9559 (accessed 11 March 2025)

14 British Academy (2024). Public trust in science-for-policymaking. Available at: https://www.thebritishacademy.ac.uk/publications/public-trust-in-science-for-policymaking/ (accessed 11 March 2025)

15 Royal Society (2022). The online information environment. Available at: https://royalsociety.org/news-resources/projects/online-information-environment/ (accessed 11 March 2025)

The role of science in national security

A resilient research system underpins a resilient society. One of the essential purposes of the domestic science system is the essential role it plays in enabling to UK to anticipate, adapt and respond to the landscape of existing and emerging national security threats.

Science plays a crucial role in detecting threats, developing protective measures and navigating vulnerabilities. As science and technology become increasingly central to geopolitics, the UK must strategically leverage its scientific capabilities to maintain and enhance its competitive edge. This especially requires strategic planning to ensure that the UK research system has the capability and capacity to be called upon, and that the education and skills system are producing the mathematically and scientifically literate workforce the national security system will require.

British scientific advances have often been essential in rapidly developing defence technologies and doctrines in the face of external threats. The first major Royal Society policy publication in 1664 was a response to a commission from the Navy Board on improving the domestic supply of timber in the wake of a series of naval defeats in the Anglo-Dutch wars. The mid-twentieth century saw the development of radar by Sir Robert Watson-Watt FRS, the turbojet engine of Sir Frank Whittle FRS, and the code-breaking devices of Alan Turing FRS. Britain retains significant defence-relevant science and engineering capabilities to this day, from operational research to communications technologies to directed energy weapons.

A resilient and agile system is needed to enable these developments, balancing long-term strategic research areas against emerging short-term needs. However, the research system can only absorb and respond to irruptive events if there is enough capacity in the system, otherwise other meaningful work is disrupted. As with the role of science in the economy, the research system is not just about creating cutting edge research, but also a reservoir for knowledge and skills which may become important (and exploitable) later.

Emerging global threats

Emerging technology areas have the potential to transform both the scale and nature of the challenge faced by 2040, with military technologies becoming increasing intelligent, interconnected, distributed and digital[16]. Developments in robotics and AI are increasing the use of autonomous systems in combat and surveillance, quantum technologies have the potential to transform communications and sensing, and new materials and cheaper ways of printing essential parts will lead to reduced costs.

The implications of the application of big data and data-driven technologies, such as AI, have profound implications for the relationship between scientific research and defence. State-sponsored cyber threats have become more frequent, sophisticated and intense, with a three-fold increase in 2023 of 'nationally significant' attacks overall[17].

16 NATO Science & Technology Organization (2020). Science & Technology Trends 2020-2040. Available at: https://www.nato.int/nato_static_fl2014/assets/pdf/2020/4/pdf/190422-ST_Tech_Trends_Report_2020-2040.pdf (accessed 11 March 2025)

17 National Cyber Security Centre (2023). NCSC Annual Review 2023. Available at: https://www.ncsc.gov.uk/collection/annual-review-2023 (accessed 11 March 2025)

This contributes to a developing risk to the security of research[18]. State-backed and criminal actors may attempt to steal cutting-edge research, technologies or sensitive data, impacting the UK's economic and competitive advantage. They might infiltrate research institutions to gain access to sensitive or classified information, or to misappropriate dual-use technologies for harmful activities, including military or surveillance applications.

Data poisoning attacks, where adversaries manipulate training data to compromise machine learning models, pose an emerging threat to both research and defence systems by causing misclassifications, faulty autonomous operations, and misinterpretation of intelligence, undermining trust and operational integrity[19]. These vulnerabilities could lead to strategic disadvantages and significant resource expenditures to address their impacts. Stringent data validation, anomaly monitoring and resilient algorithms are required to mitigate these risks and protect critical systems.

The use of space and counterspace technologies has seen an uptick in recent years in the development and testing of anti-satellite (ASAT) weapons, electronic warfare tactics and cyber operations aimed at compromising space-based assets in recent years. Beyond hard technological capabilities, the Center for Strategic and International Studies has recently warned of a "normalisation of deviance" in orbital activities, where risky behaviours become standard practice, potentially escalating tensions and the likelihood of conflicts in space[20].

There is also a national security impetus to the long-term strategies needed to tackle climate change. Climate change is a multifaceted and cascading threat with far-reaching consequences for public health, migration and resource security. It will have a direct impact on the geopolitical landscape as states adapt to these challenges, and an increase in the number of ungovernable territories gives more opportunity for non-state actors. Managing these risks requires long-term policies, including the development of clean energy systems and strategic capabilities.

National security and the research system

Three core principles underpin the role of science in national security.

1. every security challenge presents opportunities for innovation.
2. agility is essential in responding to adversaries and adapting to dynamic threats and circumstances.
3. over-reliance on rigid strategies is risky; flexibility and adaptability are key to managing unforeseen crises effectively.

18 National Protective Security Authority (n.d.). Trusted Research. Available at: https://www.npsa.gov.uk/trusted-research (accessed 11 March 2025)

19 Chaalan T., Pang S., Kamruzzaman J., Gondal I., and Zhang X. (2024). The Path to Defence: A Roadmap to Characterising Data Poisoning Attacks on Victim Models. ACM Comput. Surv. 56, 7, Article 175, 39 pages. Available at: https://doi.org/10.1145/3627536 (accessed 11 March 2025)

20 Center for Strategic and International Studies (2024). Space Threat Assessment 2024. Available at: https://www.csis.org/analysis/space-threat-assessment-2024 (accessed 11 March 2025)

Current pressures on the long-term financial sustainability of universities, and of research performing organisations more generally, have knock on effects on the ability of these organisations to maintain the necessary agility required. Portfolio simplification in response to these pressures can lead universities to close programmes, especially in areas such as Chemistry and Languages, restricting the supply of future talent, knowledge stocks and research capabilities. Increasing dependence on cross-subsidy from international students exposes universities if the countries sending those students were to change policy, but also limits the number of places taken up by students that will ultimately be suitable for security clearance.

These challenges also have an impact of the ability of state organisations to intelligently access relevant knowledge. There is value in training future decision-makers in research-intensive environments that foster horizontal connections across fields, and in ensuring long-term career and knowledge porosity across sectors (academia, government, industry) in developing a more resilient ecosystem that can re-direct people as circumstances require.

The unpredictable nature of future developments requires the maintenance of a broad reservoir of knowledge, techniques and processes that are strategically significant and may prove essential in the future, but which are not maintained organically in the private sector, due to not being readily commercialised, nor in the university system, due to not being areas of active academic enquiry or student demand. Without strategic intervention there is a risk of atrophying capability in fields such as such as Radio Science, Metallurgy and Energetics.

Historically, the National Laboratories have played an important role in maintaining these capabilities but have significantly declined as a proportion of the UK science landscape over the past four decades. This is mirrored in the size of the defence specific national labs, declining from approximately 9,000 scientific and technical staff employed by the Defence Evaluation and Research Agency (DERA) in 1995 to approximately 5,000 total staff in all functions by its successor, the Defence Science and Technology Laboratory (DSTL) in 2023[21, 22].

21 Coopey, Richard. (2002). Cold War, Hot Science: Applied Research in Britain's Defence Laboratories 1945-1990. British Journal for the History of Science; Norwich Vol. 35, 127, PP 484-485

22 UK Government (2023). Defence Science and Technology Laboratory annual report and accounts 2022 to 2023. Available at: https://www.gov.uk/government/publications/defence-science-and-technology-laboratory-annual-report-and-accounts-2022-to-2023 (accessed 11 March 2025)

BOX 1

The Heilbronn Institute and skills development

The Heilbronn Institute for Mathematical Research (HIMR) offers a potential model in addressing market failures in skills development. Co-run by the Government Communications Headquarters (GCHQ) and the academic mathematics community, it is dedicated to advancing knowledge in quantum information science, cryptography, and applied mathematics. Its work focuses on fundamental research in these areas while also addressing practical applications, particularly in secure communications and the development of emerging technologies. The institute fosters collaboration between academic institutions, government and industry, with the aim of contributing to progress in fields that have both scientific and societal relevance.

A key component of the Heilbronn Institute's activities is its annual summer school program, designed to engage and develop talent in quantum science, mathematics and cryptography. These programs provide students with an opportunity to learn from experts through lectures, workshops and collaborative problem-solving sessions. Participants gain a deeper understanding of both the theoretical underpinnings and real-world applications of cutting-edge topics in quantum technologies and security systems.

By offering these educational opportunities, the Heilbronn Institute supports the growth of skilled professionals and researchers who can contribute to areas of national interest while maintaining their academic careers.

The summer schools also help build connections within the scientific community, encouraging knowledge exchange and fostering future collaboration across disciplines. Through these initiatives, the Heilbronn Institute seeks to strengthen the foundation for ongoing innovation in critical areas of research.

Building resilience to natural hazards

The COVID-19 pandemic underlined the importance of societal resilience, but another pandemic is only one of many potential threats, and the risk landscape we face is changing. Sustained global warming will lead to an increase in the frequency and intensity of extreme weather events such as heat waves, flooding and wildfires[23]. There are a growing number of concerns relating to natural hazards that could have a severe impact on the UK. It is therefore critical that the UK has the science skills, infrastructure and policy environment to support resilience in the future.

The National Risk Register[24] notes that 'government has comprehensive plans to build resilience to specific risks' and cites the following strategies: Net Zero Strategy (2021)[25]; National Cyber Strategy (2022)[26]; Government food strategy (2022)[27]; British energy security strategy (2022)[28]; and the UK Biological Security Strategy (2023)[29]. Each of these strategies emphasises the importance of science and new technology in responding to risks, with some relying on developments yet to be fully established.

Current approach to risk assessment

The current approach to risk assessments in the UK has been subject to significant scrutiny post the COVID-19 pandemic. The House of Lords report on preparing for extreme risks highlights a critical gap in the UK's emergency response framework: the lack of transparency, public engagement and independent challenge[30]. The report criticises the obscurity around national risk assessment processes, suggesting that public engagement should be integral to the risk assessment process from start to finish.

Another potential issue is how the current approach deals with ambiguity and uncertainty. Even with accurate scientific data, the success of resilience and response efforts depends heavily on policy decisions and societal attitudes[31]. Failures in these areas can compromise the entire system, as for example, in the case of the Fukushima Daiichi nuclear disaster in 2011.

23 UK Parliament (2021). House of Lords Select Committee on Risk Assessment and Risk Planning, Preparing for Extreme Risks: Building a Resilient Society. Available at: https://committees.parliament.uk/publications/8082/documents/83124/default/ (accessed 11 March 2025)

24 UK Government (2023). National Risk Register 2023. Available at: https://www.gov.uk/government/publications/national-risk-register-2023 (accessed 11 March 2025)

25 UK Government (2021). Net Zero Strategy: Build Back Greener. Available at: https://www.gov.uk/government/publications/net-zero-strategy (accessed 11 March 2025)

26 UK Government (2022). National Cyber Security Strategy 2022. Available at: https://www.gov.uk/government/publications/national-cyber-strategy-2022/national-cyber-security-strategy-2022 (accessed 11 March 2025)

27 UK Government (2022). Government Food Strategy. Available at: https://www.gov.uk/government/publications/government-food-strategy/government-food-strategy (accessed 11 March 2025)

28 UK Government (2022). British Energy Security Strategy. Available at: https://www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy (accessed 11 March 2025)

29 UK Government (2023). UK Biological Security Strategy. Available at: https://www.gov.uk/government/publications/uk-biological-security-strategy (accessed 11 March 2025)

30 UK Parliament (2021). House of Lords Select Committee on Risk Assessment and Risk Planning, Preparing for Extreme Risks: Building a Resilient Society. Available at: https://committees.parliament.uk/publications/8082/documents/83124/default/ (accessed 11 March 2025)

31 Shin, Y.A., Hyun, Y.R. (2022). What matters to citizens in crisis recovery? Being listened to, action, and confidence in government. Policy Sci 55, 255–281. Available at: https://doi.org/10.1007/s11077-022-09454-6 (accessed 11 March 2025)

Though the resulting disaster was caused by a collection of errors, one key failure was in the Tokyo Electric Power Company ruling out the possibility of tsunami damage in a one-page memo[32], underlining the significant underestimation of tsunami risk[33]. This underlines the importance of the interconnect between science and policy, and ensuring that the right channels exist to appropriately assist and support policy makers.

Related to this is the need to ensure current risk assessments in the UK sufficiently account for the changing context of risks within a dynamic climate environment[34]. As both the climate and societal infrastructure evolve, it is crucial to integrate these changes into risk assessments. Acute events, such as extreme weather, are embedded within chronic risk environments, and addressing them in isolation can lead to significant gaps in resilience planning and risk assessment. Science and research can help bridge these gaps in knowledge and help policy makers to better understand the risk landscape in relation to the UK. Additionally, there is a widespread lack of understanding regarding climate change adaptation compared to mitigation.

This gap hampers effective discussions on how to adapt infrastructures such as housing and agricultural systems. Much of the climate change risk currently faced by the population is already present, such as with flooding, though the intensity and frequency of these events is likely to increase[35]. This underscores the urgent need for long-term infrastructure investments and mechanisms that extend beyond typical governmental terms.

Modelling and data

The UK is often effective in its utilisation of data and modelling to enhance societal resilience to natural hazards. These efforts are particularly evident in the areas of diagnosing and observing issues related to natural disasters. Agencies such as the Met Office provide world leading insights and research on natural hazards, including space weather and climate. Universities in the UK produce some of the most cutting-edge modelling and data regarding natural hazards, for example University College London established the Warnings Research Centre (WRC) focusing on research that brings together global expertise to explore the role of warnings in managing vulnerabilities, hazards, risks and disasters for all natural and human-made hazards and threats[36]. This is the only academic centre of its kind in the world[37].

32 Marshall, M. (2011). Fukushima was certified tsunami-proof. New Scientist. Available at: https://www.newscientist.com/article/dn20524-fukushima-was-certified-tsunami-proof/ (accessed 11 March 2025)

33 Synolakis, C. and Kânoğlu, U. (2015). The Fukushima Accident Was Preventable. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 373(2053), p.20140379. Available at: https://doi.org/10.1098/rsta.2014.0379 (accessed 11 March 2025)

34 Kythreotis, A.P., Hannaford, M., Howarth, C. and Bosworth, G. (2024). Translating climate risk assessments into more effective adaptation decision-making: The importance of social and political aspects of place-based climate risk. Environmental Science & Policy, 154, p.103705. Available at: https://doi.org/10.1016/j.envsci.2024.103705 (accessed 11 March 2025)

35 Environment Agency (2021). Living better with a changing climate: Report to Ministers under the Climate Change Act. Available at: https://assets.publishing.service.gov.uk/media/61695c50e90e071979dfec5c/environment-agency-climate-change-adaptation-report.pdf (accessed 11 March 2025)

36 UCL (2021). Warning Research Centre. About Us. Available at: https://www.ucl.ac.uk/sts/warning-research-centre/wrc-about-us (accessed 12 March 2025)

37 REAP. (2022). The University College London Warning Research Centre joins REAP. Available at: https://www.early-action-reap.org/university-college-london-warning-research-centre-joins-reap (accessed 12 March 2025)

However, there are barriers to improving the quality of current data and models. One significant barrier to improving data and modelling of natural hazards is the lack of interoperability of data. Different agencies and organisations often collect and store data in different formats, making it difficult to integrate and analyse them. A lack of standardisation, availability of, and access to data, and a diverse range of stakeholders producing and holding data can create barriers to interoperability[38, 39]. Understanding what data are needed, who owns what data, and where it is held, is essential for enabling scientific research which can help to build and improve models and thus improving societal resilience and our understanding of the risk landscape[40].

An interdisciplinary approach

The interdependency of risks means that an interdisciplinary approach to research and societal research is essential. For example, a severe weather event can lead to flooding, which in turn can disrupt transportation networks, power supplies and healthcare services. The interconnected nature of these risks means that addressing them in isolation is insufficient[41]. However, siloed working remains an issue across academia, government departments and industry.

The Natural Hazards Partnership (NHP), established 2011, is a good example of where efforts have been made to embed an interdisciplinary approach to natural hazards[42]. The NHP is a collaborative initiative in the UK that brings together expertise from various public sector agencies to provide scientific advice on natural hazards. The partnership includes organisations such as the Met Office, the British Geological Survey, and the UK Centre for Ecology & Hydrology. However, barriers to interdisciplinary working are still a critical issue (such as lack of interoperability of data), as the broader systemic issues that impede greater collaboration and integration of different disciplines into research projects remain[43, 44].

38 Migliorini, M. *et al*. (2019) The role of data interoperability in disaster risk reduction: barriers, challenges and regional initiatives. Contributing Paper to GAR 2019. Available at: https://www.undrr.org/publication/role-data-interoperability-disaster-risk-reduction-barriers-challenges-and-regional (accessed 12 March 2025)

39 Waterman, L., Rivas Casado, M., Bergin, E., & McInally, G. (2021). A Mixed-Methods Investigation into Barriers for Sharing Geospatial and Resilience Flood Data in the UK. Water, 13(9), 1235. Available at: https://doi.org/10.3390/w13091235 (accessed 12 March 2025)

40 UK Parliament (2021). House of Lords Select Committee on Risk Assessment and Risk Planning, Preparing for Extreme Risks: Building a Resilient Society. Available at: https://committees.parliament.uk/publications/8082/documents/83124/default/ (accessed 11 March 2025)

41 Royal Academy of Engineering (2022). National Security Risk Assessment Methodology Review. Available at: https://raeng.org.uk/policy-and-resources/engineering-policy/security-and-resilience/nsra (accessed 12 March 2025)

42 Met Office (n.d.). The Natural Hazards Partnership (NHP). Available at: https://www.metoffice.gov.uk/services/government/environmental-hazard-resilience/natural-hazards-partnership (accessed 12 March 2025)

43 Royal Academy of Engineering (2022). Building resilience: lessons from the Academy's review of the National Security Risk Assessment methodology. Available at: https://raeng.org.uk/policy-and-resources/engineering-policy/security-and-resilience/nsra (accessed 12 March 2025)

44 Campaign for Science and Engineering (2021). The role of the UK Government in supporting interdisciplinary research. Available at: https://www.sciencecampaign.org.uk/analysis-and-publications/detail/role-of-govt-supporting-interdisciplinary-research/ (accessed 12 March 2025)

Education, communication, and public understanding

Effective communication and public understanding are critical during an emergency response to a natural hazard[45, 46, 47]. As was shown during the pandemic, poor communications and misinformation combined with a poor understanding of risks and probabilities had a measurable impact on the effectiveness of non-pharmaceutical interventions such as mask wearing[48].

Technical agencies, such as the Met Office and the Environment Agency play a key role in conveying information to both government bodies and the public. The importance of effective communications during a disaster response has been well documented[49, 50], but as important are public attitudes and understanding of risks. It can sometimes seem as though there is a cultural aversion to discussing risk in the UK, unlike in some Nordic countries where public discourse on risk preparedness is more common. For example, Sweden takes a much more open approach in terms of engaging with the public, ensuring that the public understands the kinds of threats that the country is facing, and how they can prepare themselves[51].

Currently, the lack of understanding among the public is likely to inhibit effective risk preparation and response. For instance, misconceptions about climate change and other hazards can lead to inadequate personal and community-level preparedness. Enhancing education on these topics can help bridge this gap.

Conclusion

Science produces benefit to humanity. Any future science system should be optimised to maximise this. Science produces direct benefits to the economy. Technological innovation leads to productivity gains, as well as allowing for new forms of goods and services. These create immediate returns on investment for investors (whether state, company or individual), and create broader spillover effects to the economy more generally.

45 Vandrevala, T., Morrow, E., Coates, T. *et al*. (2024) Strengthening the relationship between community resilience and health emergency communication: a systematic review. BMC Global Public Health 2, 79 (2024). Available at: https://doi.org/10.1186/s44263-024-00112-y (accessed 12 March 2025)

46 Ma, C., Qirui, C. and Lv, Y. (2023). One community at a time: promoting community resilience in the face of natural hazards and public health challenges. BMC Public Health, 23(1). Available at: https://doi.org/10.1186/s12889-023-17458-x (accessed 12 March 2025)

47 UNDRR (n.d.). Essential Seven: Understand and Strengthen Societal Capacity for Resilience. Available at: https://www.unisdr.org/campaign/resilientcities/home/article/essential-seven-understand-and-strengthen-societal-capacity-for-resilience.html (accessed 12 March 2025)

48 Caceres, M.M.F., Sosa, J.P., Lawrence, J.A., Sestacovschi, C., Tidd-Johnson, A., Rasool, M.H.U., Gadamidi, V.K., Ozair, S., Pandav, K., Cuevas-Lou, C., Parrish, M., Rodriguez, I. and Fernandez, J.P. (2022). The impact of misinformation on the COVID-19 pandemic. AIMS Public Health, 9(2), pp.262–277. Available at: https://doi.org/10.3934/publichealth.2022018 (accessed 12 March 2025)

49 Fakhruddin, B., Clark, H., Robinson, L. and Hieber-Girardet, L. (2020). Should I stay or should I go now? Why risk communication is the critical component in disaster risk reduction. Progress in Disaster Science, 8, p.100139. Available at: https://doi.org/10.1016/j.pdisas.2020.100139 (accessed 12 March 2025)

50 Doyle E., and Becker, J.S. (2022). Understanding the Risk Communication Puzzle for Natural Hazards and Disasters. Oxford Research Encyclopedia of Natural Hazard Science. Available at: https://doi.org/10.1093/acrefore/9780199389407.013.208 (accessed 12 March 2025)

51 UK Parliament (2021). House of Lords Select Committee on Risk Assessment and Risk Planning, Preparing for Extreme Risks: Building a Resilient Society. Available at: https://committees.parliament.uk/publications/8082/documents/83124/default/ (accessed 11 March 2025)

Science also provides other, non-economic (or not purely economic) instrumental benefits to society. Scientific understanding and technological developments are both necessary in anticipating and responding to societal stressors (climate change, demographic shift, etc) and shocks to the system (defence, disease, disaster).

A population facing an uncertain future requires practical adaptability and the capacity to think both imaginatively and critically. Science plays an essential role in education in providing specific knowledge and skillsets currently required by the economy but also serves as a tool for developing adaptive practical thinking more generally, to better adapt and respond to rapid change.

In each of these dimensions, it is not just the new or the cutting edge that is important. There needs to be capacity in the system to allow for responses to emergent opportunities or threats without derailing longer term work. Bodies of knowledge or skills need to be maintained that might become of sudden economic or strategic importance in the future. And a thriving culture of curiosity-driven science needs to be maintained not just to realise these instrumental benefits most effectively, but also for its fundamental role in driving a broader curious and adaptive culture.

A resilient science system requires a balanced approach to funding, ensuring support for basic, applied and mission-driven research. While applied science drives technological innovation, fundamental research underpins long-term breakthroughs, many of which are unpredictable in their economic impact. A diverse research portfolio, including high-risk, high-reward projects, will sustain the UK's leadership in emerging fields. Policymakers should ensure funding mechanisms protect foundational research, allowing the UK to remain competitive while fostering an environment that encourages curiosity-driven exploration alongside and in collaboration with those working on practical application.

Why is long-term planning important?

Introduction

The UK science system remains an important national asset but faces a range of structural and financial challenges that jeopardise its long-term sustainability. This section explores the dynamics shaping UK research and development, including issues in funding, talent retention and international collaboration. It addresses some of the historic attempts to address these over the past 80 years and summarises some of the key issues remaining today.

Opportunity costs

Short-term thinking in UK science policy has significant opportunity costs. Policy instability, excessive focus on immediate outcomes, and lack of long-term vision can deter foreign investors, reduce the UK's global competitiveness, and hinder its ability to attract the best talent or capitalise on emerging scientific fields.

The UK science system faces significant risks when policies prioritise short-term objectives over sustained, strategic investments. One of the most critical opportunity costs is the erosion of the UK's competitiveness in attracting foreign direct investment. Countries with stable, predictable policy environments are more attractive to foreign investors, particularly in fields requiring long-term commitments such as research and development.

Private sector R&D in the UK and elsewhere is financed through a range of mechanisms, each linked to the structure and stage of the firm. Large firms often rely on retained profits to fund in-house research, allowing for long-term investments aligned with strategic goals[52]. These firms typically avoid external capital to preserve control and flexibility, especially in industries with high sunk costs and long innovation cycles, such as pharmaceuticals and aerospace.

In contrast, start-up firms – particularly in high-tech sectors – commonly depend on venture capital (VC) to finance R&D. Venture capitalists are more willing than traditional investors to support risky, high-reward projects, although they often seek relatively fast exits through acquisitions or IPOs. As a result, VC-backed firms may face pressure to demonstrate early commercial promise, which can shape the nature and direction of their R&D activity.

Growth-stage firms – those beyond the start-up phase but not yet mature – may access R&D financing via capital markets, including equity issuance. However, particularly in systems with short-termist investor behaviour, this can discourage long-term, exploratory R&D in favour of nearer-term returns[53].

52 Hall, B. H., & Lerner, J. (2010). The Financing of R&D and Innovation. In B. H. Hall & N. Rosenberg (Eds.), Handbook of the Economics of Innovation.

53 Brown, J. R., Fazzari, S. M., & Petersen, B. C. (2009). Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom. Journal of Finance, 64(1), pp.151–185.

This challenge is particularly relevant in the UK context, where market-based finance is dominant. There is substantial evidence that UK capital markets exhibit short-termist tendencies, often prioritising near-term returns over long-horizon investment[54]. Such structural issues may particularly impact long-term, innovation-intensive sectors such as advanced manufacturing and green technology. Empirical data supports this: a 2022 survey of over 1,500 UK firms found that 58.8% used a payback period of three years or less when assessing investments, indicating a strong preference for quick returns[55].

These issues are especially pronounced in sectors with high upfront costs and uncertain returns. In green technologies, which require patient capital, this creates barriers to commercialisation. Similarly, in UK advanced manufacturing, capital market expectations have often led to underinvestment in R&D relative to global peers[56].

In the life sciences sector, the mismatch between R&D timelines and investment horizons is particularly clear. Parliamentary evidence noted that while developing a pharmaceutical company may take 15 – 20 years, venture capital firms typically seek to exit within six to eight years[57]. This results in a funding gap at the scale-up stage, limiting the UK's ability to develop large, globally competitive firms. The 2017 Patient Capital Review estimated a £4 billion annual financing gap for later-stage growth, with follow-up studies identifying short-term VC cycles as a key constraint on deep-tech innovation[58].

These issues are only exacerbated by fragmented public funding and inconsistent policies which reduce investment in the most innovative long-term projects, making the UK less appealing for foreign companies looking to establish R&D operations. This creates a vicious cycle where underinvestment leads to reduced innovation capacity, further eroding the UK's competitive position.

Countries with more stable science policies realise the benefits in the long run. Germany, for instance, maintains consistent R&D funding strategies that prioritise long-term innovation such as the High-Tech Strategy, which focuses on fostering public-private partnerships and investing in key technologies such as AI, green energy and products, sustainable chemistry and advanced manufacturing. This approach has enabled Germany to maintain a competitive edge in global markets while attracting substantial foreign direct investment into its innovation ecosystem.

In contrast, the UK's policy landscape has been marked by frequent shifts. The Industrial Strategy Challenge Fund (2017), designed to align innovation with strategic priorities, was replaced in 2021 by the Innovation Strategy. Such abrupt changes disrupt long-term planning.

54 Cambridge Industrial Innovation Policy (2024). UK Innovation Report 2024. University of Cambridge.

55 Barker, R., Mayer, C., & Gabet, R. (2023). Lifting the Long-Term Barrier: How Financial Markets Fail Innovation.

56 *Op. cit.* 54.

57 House of Lords Science and Technology Committee (2022). Life Sciences Industrial Strategy: Who's driving the bus? Available at: https://publications.parliament.uk/pa/ld201719/ldselect/ldsctech/115/11502.htm

58 HM Treasury (2017). Patient Capital Review: Industry Panel Report. Available at: https://www.gov.uk/government/publications/patient-capital-review

Further evidence comes from studies of the impact of managerial short-termism in reducing investment in long-term projects[59]. The study's findings suggest that countries with policies that incentivise immediate returns over sustained growth are less likely to attract foreign investment in R&D and high-tech industries. This aligns with observations in the UK, where fragmented and short-lived initiatives fail to provide the stability needed for long-term commitments.

Future implications

The UK's short-term approach to science policy has far-reaching implications. If left unaddressed, it has the potential to limit innovation capacity, and reduce the UK's influence in global science and technology. The solution is to emulate international best practices by implementing stable funding mechanisms and predictable regulatory frameworks. By addressing policy instability and fostering a predictable environment, the UK can enhance its global competitiveness and secure its position as a leader in science.

Past UK approaches to science strategy

The UK's post-war science and research system was initially shaped by the experience of wartime mobilisation and a national commitment to technological and industrial reconstruction[60]. From the late 1940s through to the 1970s, science policy in Britain was marked by high levels of public investment and a clear role for government departments in sponsoring and coordinating research activity. At its peak in the 1960s, total expenditure on R&D reached approximately 2.3% of GDP, with government funding accounting for the majority share. A substantial proportion, approximately half, was directed towards defence which dominated the public R&D landscape alongside strategic investments in energy, transport and agriculture.

This period also reflected a broader and more fluid understanding of research than exists today. The now-familiar distinctions between 'basic' and 'applied' science were not rigidly defined in public discourse or policymaking. Instead, terms like 'fundamental research' were commonly used to describe long-term or general investigations that could benefit entire industrial sectors. Research was often viewed as a public good in its own right, whether carried out by government laboratories, public corporations or industry. The Department of Scientific and Industrial Research (DSIR), active until 1965, played a key role in expanding the UK's research capacity, supporting university science, and promoting collaborative efforts such as the Research Associations, which enabled industry to co-fund research of shared interest. In this system, government financing and industrial execution of research were closely linked.

59 Edmans A., Fang V., and Lewllen K. (2020). Managerial Short-Termism and Investment. Review of Finance 24(2), pp. 305–344.

60 This section is heavily indebted to The British Academy (2019) Lessons from the History of UK Science Policy. Available at: https://www.thebritishacademy.ac.uk/publications/policy-histories-lessons-history-uk-science-policy/

However, from the 1980s onwards, this model underwent significant change. Under the government of Margaret Thatcher, public policy shifted sharply towards a market-led approach[61]. The 1987 science policy reforms, influenced by the Number 10 Policy Unit, moved decisively away from state support for 'near-market' and applied research. Public funding was concentrated instead on what was termed 'curiosity-driven' or 'pure' science, with the assumption that commercial applications would be funded by the private sector. This marked a departure from the earlier, more interventionist model in which public and private research efforts were more tightly integrated.

At the same time, the Rothschild reforms of the early 1970s had already begun to reshape departmental research, introducing the 'customer-contractor' model and shifting responsibility for applied research onto government departments. But by the late 1980s, civil departments' R&D budgets were in sustained decline. While research councils saw relative protection or even increases in their budgets, funding for mission-driven or problem-oriented research – traditionally carried out in departmental labs or public research institutes – was progressively withdrawn. The UK's public research portfolio thus became increasingly dominated by theoretical science conducted in universities.

The accompanying expectation was that business R&D would fill the gap left by the retreat of government from applied research. However, this did not occur at sufficient scale. Between the 1960s and 1999, total UK R&D intensity fell from around 2.3% to 1.8% of GDP, a drop driven by reductions in both government and company spending.

Business investment in R&D has remained heavily concentrated, particularly in sectors such as pharmaceuticals, automotive and aerospace, with large parts of the services and consumer economy investing very little in research. The structural assumption that private enterprise would lead to applied innovation proved over-optimistic, especially given the lack of policy levers to steer or coordinate that investment.

Gordon Brown's ten-year strategy

The Ten-Year Science and Innovation Framework (2004 – 2014) was a strategy introduced by Gordon Brown during his tenure as Chancellor of the Exchequer, in collaboration with the Department of Trade and Industry (DTI). Its primary aim was to establish the UK as a global leader in science and innovation, recognising these areas as essential for economic growth, productivity and societal progress. The framework sought to provide a long-term vision for science policy, ensuring stability and predictability to encourage sustained investment in research and innovation.

One of the central objectives of the framework was to increase overall R&D spending to 2.5% of GDP by 2014, with a significant contribution expected from the private sector. It also focused on enhancing funding for public research, with the government science budget doubling over the decade to support research councils, universities and scientific infrastructure. However, the framework largely preserved the focus of public support on discovery science, while applied and translational research relied on industry partnerships.

61 Agar, J. (2019) Science Policy under Thatcher.

The strategy prioritised strengthening links between universities and businesses, encouraging knowledge transfer through initiatives such as the Higher Education Innovation Fund (HEIF) and Knowledge Transfer Partnerships (KTPs). Sectors with high growth potential, including life sciences, renewable energy, and information technology, were identified as areas for targeted support. However, despite efforts to enhance commercialisation, the long-standing funding emphasis on basic science meant that challenges remained in translating research into economic benefits.

The framework achieved some successes. The UK maintained its global leadership in fields such as life sciences and made significant advancements in renewable energy, particularly offshore wind technologies. University-business collaboration was strengthened, particularly through the expansion of HEIF and KTPs, which facilitated the commercialisation of research and innovation. Efforts to promote STEM education resulted in a gradual increase in the number of students pursuing science and engineering disciplines.

However, the framework also faced challenges. The target of raising R&D spending to 2.5% of GDP by 2014 was not achieved, with spending remaining below 2%. Private sector contributions to R&D fell short of expectations, which limited progress towards this goal. Regional disparities in research and innovation capacity persisted despite efforts to establish science and innovation campuses across the UK.

As with previous governments, economic pressures, particularly those arising from the global financial crisis of 2008, constrained public spending and affected the ability to sustain long-term investment in science and innovation. Additionally, engagement from the private sector was uneven, with some industries demonstrating stronger participation than others.

The UK science system today

The UK science sector faces a range of structural and financial challenges that threaten its long-term sustainability and global competitiveness. This overview highlights some of the current key issues affecting research funding, talent retention, and international collaboration, while also exploring the systemic factors shaping the future of British R&D. Figures A and B give an overview of which sectors perform and fund research and development in the UK.

FIGURE 1

Expenditure on R&D in the UK by sector performing the R&D, 2022

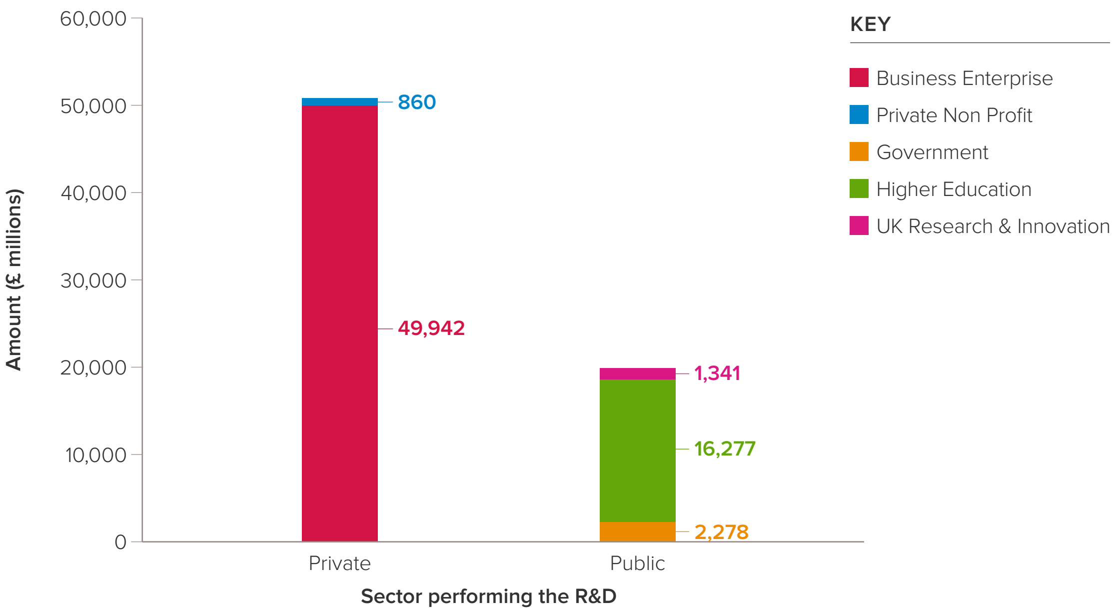
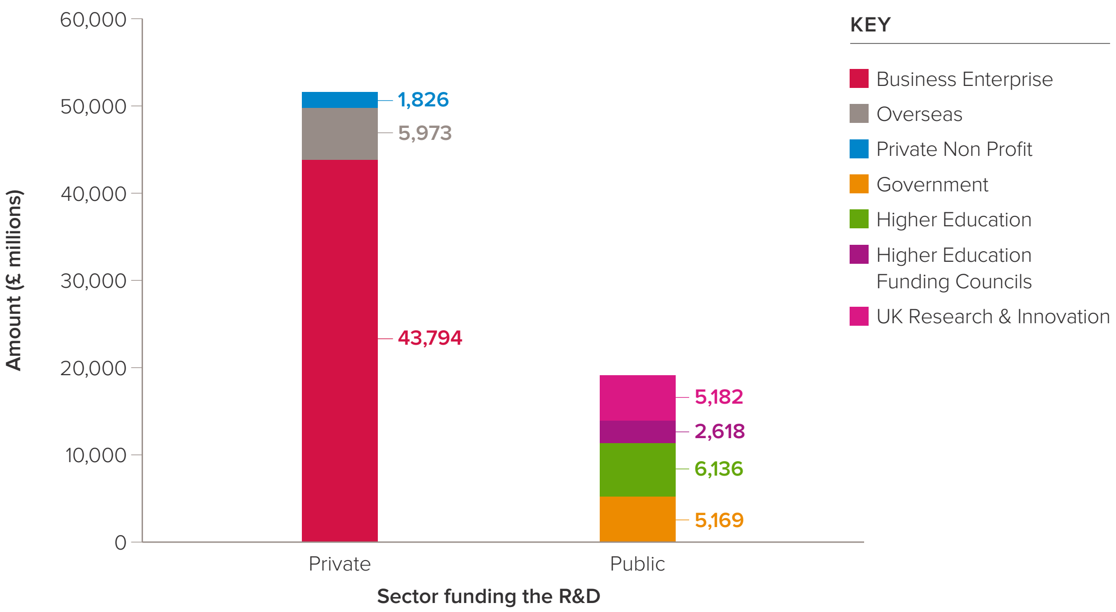


FIGURE 2

Expenditure on R&D in the UK by sector funding the R&D, 2022



Financial vulnerability in the higher education and public/non-profit research sector poses a threat to the sustainability of the UK's science system. Universities are facing particularly difficult financial headwinds, with Full Economic Cost (FEC) recovery rates for research steadily declining over the past decade (down to 68.1% in 2022/23, causing a sector-wide deficit of £5 billion)[62]. Much of this sector relies on large cross-subsidies, with international student fees playing a crucial role in supporting publicly funded research. Universities UK have predicted that international fee income will account for between 33 – 66% of all course fee income by 2026/27 (compared to a range of 24 – 64% in 2021/22)[63]. Yet international student numbers have started to decline, and many research programmes within universities could become financially unsustainable, with larger, more research-intensive and specialist providers being particularly exposed to any significant decline. Inflationary pressures are also particularly acute in key areas of research. The 2022 Gross domestic expenditure on R&D (GERD) release shows that the UK invested £70.7 billion in R&D that year. This continues an increase compared with £61.8 billion and £66.3 billion invested in 2020 and 2021 respectively, in current prices. However, high inflation over this period has negated this cash increase, with levels of R&D investment in constant prices plateauing since 2021[64]. For example, inflation linked to laboratory research has risen over recent years[65], and whilst the cost of chemicals rose roughly in line with inflation from 2015, it exceeded it in 2022 and 2023[66]. There are already clear signs of financial pressures impacting on higher education providers, with around 70 out of nearly 290 providers in the UK announcing proposed restructures or redundancies.

The treatment of intellectual property (IP) remains an area of challenge, with disagreements over management and sharing creating tension among universities, businesses, and other stakeholders. Collaborations between companies and universities have stalled, with a 5% decline in activity reported in 2023. Large companies reduced collaborations by 8.8%, while small and mid-sized businesses cut back by 3.5%. Despite this, there has been some progress. The 2023 Independent Review of University Spinouts put forward several recommendations to help improve the creation and growth of university spinouts in the UK. Many universities have adopted best practice recommendations around equity and embarked on pilots for shared Technology Transfer Offices[67].

62 Office for Students (2024) Annual TRAC 2022-23 Update. Available at: https://www.officeforstudents.org.uk/publications/annual-trac-2022-23/ (accessed 11 March 2025)

63 PWC (2024). UK Higher Education Financial Sustainability Report. Available at: https://www.pwc.co.uk/industries/government-public-sector/education/financial-sustainability-of-uk-higher-education-sector.html (accessed 12 March 2025)

64 Campaign for Science and Engineering. "Increases in R&D Investment Are Not Keeping Pace with Inflation." Accessed February 26, 2025. URL: https://www.sciencecampaign.org.uk/analysis-and-publications/detail/increases-in-rd-investment-are-not-keeping-pace-with-inflation/.

65 Leeming J. (2024) UK university departments on the brink as higher-education funding crisis deepens. Available at: https://www.nature.com/articles/d41586-024-03079-w (accessed 12 March 2025)

66 Burke M. (2024). The Chemicals Cost Crisis. Available at: https://edu.rsc.org/analysis/the-chemicals-cost-crisis/4018689.article (accessed 12 March 2025)

67 Royal Academy of Engineering (2025). UK Spinouts: a status update. Available at: https://raeng.org.uk/media/pdmguaxs/uk-spinouts-a-status-update-2025-final.pdf (accessed 31 March 2025)

The UK faces potential STEM skill shortages, partly due to a lack of qualified teachers capable of training the next generation of R&D professionals. Additionally, international competition, lack of dedicated funding, and debt perceptions of students makes PhD recruitment more challenging, further threatening the pipeline of skilled researchers. The shortage of people with the necessary STEM skills impedes improvements to productivity, economic growth and the fulfilment of wider policy goals, such as net zero and energy security.

The prevalence of precarious and less competitively paid research positions risks driving talented R&D professionals out of the sector. This issue disproportionately affects minority groups and caregivers, who are already underrepresented in research and development fields.

High inflation exacerbates these challenges by reducing the real-terms value of nominal increases in the R&D budget. As the cost of conducting scientific research rises, the effectiveness of government investment diminishes.

The UK lags behind other advanced economies in total R&D spending and risks falling further behind as countries commit significantly higher investments. Comparable countries such as Germany, Switzerland, Japan and South Korea spend a higher percentage of GDP on R&D than the UK, with some setting even more ambitious targets for the future (Table 1). Without matching these efforts, the UK's global competitiveness in science may erode.

The lack of an international science strategy may also undermine the UK's ability to attract the brightest and the best in science. Europe remains an essential source of scientific collaboration for the UK. However, uncertainties surrounding future Horizon Europe association risk damaging these critical relationships. UK visa arrangements, among the most expensive in the world for migrants and sponsors, act as a significant barrier to attracting skilled R&D professionals. These high costs risk deterring the talent necessary to sustain the UK's science ambitions.

TABLE 1

R&D spend as a percentage of GDP for selected countries (OECD data)

Country	Total R&D Spend (Million US dollars, PPP converted)	Spend on R&D as a percentage of GDP	Year of Data	R&D Investment Targets
Germany	157,503	3.1%	2022	3.5% of GDP by 2025
Japan	188,831	3.4%	2022	4% of GDP by 2025
Switzerland	21,957	3.3%	2021	No specific target
South Korea	129,299	4.8%	2022	5% of GDP by 2045
UK	102,539	2.8%	2022	2.4% of GDP by 2027

Drivers of future change

Introduction

Numerous challenges face the UK science ecosystem with significant levels of uncertainty as to how those challenges may unfold over the next 20 years. An example of this is the changing demography of the UK as people live longer[68, 69]. Whilst this will have societal and economic implications, the way in which these play out is complex and interdependent on other drivers of change. These drivers can be broadly categorised into political, economic, societal, technological and environmental factors. Within these categories, there are critical uncertainties, specific drivers with the potential to have significant impact on the future, and with a significant degree of uncertainty on how they might develop and change the science ecosystem.

There are numerous critical uncertainties. The following illustrate some of the most pressing issues for science in the UK including the relationship between science and government, uneven access to resources, the approach taken to tackling climate change, and the interaction between regional, national and international policymaking. The interplay of these uncertainties will shape the future of science in the UK.

Relationship between science and governments

The global context in which the UK science system of 2040 will operate is uncertain. The way in which governments access and interact with scientific research and advice shifts over time. Government engages with science in multiple ways, from funding research to incorporating scientific advice into policy decisions. Science is a global collaborative endeavour and so changes to this relationship in one country can affect everyone.

Whilst the value of utilising and engaging with scientific evidence was broadly apparent during the COVID-19 pandemic[70], there are signs that geopolitical, technological, environmental and demographic changes are increasingly threatening the values that drive science for the benefit of humanity[71]. The global political uncertainties, alongside a rising distrust and dissatisfaction with the institutions of government, could result in significant changes to the future domestic and global political landscape. Such changes can both directly and indirectly undermine trust in science and create a more hostile environment where funding for research becomes more centralised and directed by government.

68 ONS (2024). National population projections 2022-based. Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/bulletins/nationalpopulationprojections/2022based (accessed 13 March 2025)

69 Centre for Better Aging (2023). State of Aging 2023. Available at: https://ageing-better.org.uk/resources/summary-report-state-ageing-2023 (accessed 12 March 2025)

70 UK COVID-19 Inquiry (2024). Module 1 Report: The Resilience and Preparedness of the United Kingdom. Available at: Module 1 report: The resilience and preparedness of the United Kingdom – UK Covid-19 Inquiry (accessed 12 March 2025)

71 Ambrose M. (2024). Science Policy Outlook for the Second Trump Presidency. Available at: https://ww2.aip.org/fyi/science-policy-outlook-for-the-second-trump-presidency (accessed 12 March 2025)

Climate change is a particularly significant challenge and requires a coordinated global response. Despite this, geopolitical stability and the willingness of nations to collaborate has become increasingly uncertain. The Paris Agreement, adopted in 2015, was a landmark example of global collaboration, aiming to limit global warming to well below 2°C above pre-industrial levels. Progress on the aims of the agreement has been slow, and the geopolitical landscape has changed significantly since its inception[72]. The US government elected to withdraw from the Paris Agreement for a second time in January 2025, and shifting political powers and trends in Europe could continue to create greater instability and reduced collaboration on climate change[73] If energy prices are rising, and living standards are falling, the political will to invest and support climate policies may be challenged, and the future policy approach to this critical issue is uncertain. Global uncertainty over climate science and the funding of climate science creates a challenging context for the UK science system, and will affect the way it communicates its priorities, and develops its international commitments.

Uneven access to resources

Uneven access to resources is a critical issue that impacts society, and can hinder innovation and progress. Inequality in the UK manifests in various forms, including in economic, educational and health disparities. Regions within the UK receive differing levels of R&D investment[74], and there are differing levels of engagement with science with costal, rural and former industrial regions having limited access compared to larger cities[75].

An example of unequal access to resource can be seen within telecommunications infrastructure including gigabit-capable broadband coverage and full-fibre networks[76]. Whilst 5G mobile coverage covers approximately 42% in urban areas, only 16% of sites are covered in rural areas. These disparities limit digital access and economic opportunity in often underserved areas. Specific sectors also face pressing challenges. Within the space sector, the rising demand for satellite services strains existing infrastructure and has the potential to leave critical needs unmet, impeding growth[77].

72 Leiter, T. (2022) Too Little, Too Slow? Climate Adaptation at the United Nations Climate Change Negotiations Since the Adoption of the Paris Agreement Carbon & Climate Law Review. 16 (4) pp. 243 – 258. Available at: https://doi.org/10.21552/cclr/2022/4/5 (accessed 12 March 2025)

73 Schwägerl C. (2023). Shifting Political Winds Threaten Progress on Europe's Green Goals. Yale E360. Available at: https://e360.yale.edu/features/europe-environment-backlash (accessed 12 March 2025)

74 Forth T. and Jones R. (2020) The Missing £4bn. Available at: https://www.nesta.org.uk/report/the-missing-4-billion/ (accessed 12 March 2025)

75 British Science Association (2022). Mapping and Analysis of Science Engagement and Inequity in the UK. Available at: https://www.britishscienceassociation.org/news/new-report-inequity-science-engagement-uk (accessed 12 March 2025)

76 HM Treasury (2020). National Infrastructure Strategy: Fairer, faster, greener. Available at: https://www.gov.uk/government/publications/national-infrastructure-strategy (accessed 12 March 2025)

77 UK Parliament (2022). UK space strategy and UK satellite infrastructure – Second Report of Session 2022-23. Science, Innovation and Technology Committee. Available at: https://committees.parliament.uk/work/1194/uk-space-strategy-and-uk-satellite-infrastructure/publications/ (accessed 12 March 2025)

The way in which such inequalities play out over time will shape the science ecosystem across the UK; where investment is concentrated, who has access to opportunities, how resources or new developments interact with local populations, and how science is perceived and valued in different parts of the country.

The interaction between regional, national and international policymaking

In an interconnected world and globalised economy, there is a tension between regional, national and global approaches to policymaking. Whilst a national approach can support delivery against domestic priorities, international collaboration and coordination remain critical. During the COVID-19 pandemic, the UK government provided support to the development of the Oxford/AstraZeneca vaccine in parallel with other national medical interventions[78]. This was alongside wider global action: the UK committed to the global initiative Covax to secure fair access to COVID-19 vaccines[79].

Many issues require a global approach. An example of this is space exploration. There are more than 14,000 satellites in low orbit around earth and 120 million pieces of debris[80]. To prevent disruption to essential communication and navigation technologies, space infrastructure situated in low orbit must be protected. Yet, there is no centralised global mechanism to achieve this.

The interplay between international, national and regional policy making can have profound impacts on science. From the fallout of protectionist policies, and potential inflationary pressure on research materials and equipment, to the potential devolution of resources, which can shift the ways in which science is funded. These types of changes are often difficult to predict over 10 year time horizons, and thus require broad principles that can be applied to numerous future scenarios and provide a degree of certainty and stability.

78 UK Government (2022). One year anniversary of UK deploying Oxford-AstraZeneca vaccine. Available at: https://www.gov.uk/government/news/one-year-anniversary-of-uk-deploying-oxford-astrazeneca-vaccine (accessed 12 March 2025)

79 UK Parliament (2021). UK response to COVID-19: International aid and diplomacy. Available at: https://commonslibrary.parliament.uk/research-briefings/cbp-9258/ (accessed 12 March 2025)

80 Bhattacharjee, N. (2024). Global push for cooperation as space traffic crowds Earth orbit. Reuters. Available at: https://www.reuters.com/science/global-push-cooperation-space-traffic-crowds-earth-orbit-2024-12-02/ (accessed 12 March 2025)

Principles

Operational principles for a future science system

As discussed in the previous section, the future is inherently uncertain. While long-term strategies have been attempted in the UK in the past, these have often been over-determined and ceased to be influential when overtaken by economic events. Any future science system must be adaptable to account for this, potentially anticipating how the strategy will be maintained and resourced in different growth scenarios, yet embody a consistent vision to be meaningful.

Articulating the principles that any future science system should embody is a foundational element in achieving this. Whichever future scenario the UK finds itself in, the science system it employs should embed the ten values that follow to maximise the benefits it can deliver for society.

Excellence

What is it?

A system that enables excellence ensures that those working across the research and innovation ecosystem are supported to deliver world-leading and impactful discovery and applied research. As the definition of excellence is dependent both on the context and objectives of the research, it should encompass a range of dimensions around the quality, robustness, relevance and potential impact of the research.

Why does it matter?

A research and innovation system that delivers excellence is essential to the UK maintaining its reputation as a world-leader for research and continuing to deliver high-quality research and attract talent and investment. Ensuring that research excellence is recognised and incentivised across the entirety of the system is important to enabling the workforce to deliver cutting-edge discovery and applied research and facilitating the pull-through of research to innovative products and processes, ultimately delivering societal impact.

Top-level dynamics of how it might shift

There has been a recent shift towards a more holistic understanding of excellence beyond traditional metrics such as publications. There is likely to be a continued expansion of the definition of research excellence to recognise the wide range of roles, institutions and people that support the UK research system. This may cause tensions amongst the research system. Balancing excellence against other principles for research funding – such as place-based funding, or principles around capacity-building or widening participation will likely be a challenge. Ensuring that world-leading research and innovation are maintained whilst building capacity across the ecosystem will ensure that the science base stays at the forefront of discoveries whilst building skills and capacity across the country.

Research integrity

What is it?

Research integrity is the adherence to ethical principles and professional standards essential for the responsible practice of research. It encompasses adherence to the scientific method, accountability for the validity of findings, openness and honesty in the dissemination of findings, and a commitment to the ethical treatment of research subjects. The development of common experimental practices, laboratory spaces and peer reviewed articles in the 17th century represent early attempts at guaranteeing and communicating research integrity.

Why does it matter?

Research integrity is essential for ensuring the reliability and trustworthiness of scientific findings. Adhering to these standards in research fosters public confidence in scientific endeavours, guaranteeing the quality of individual studies but also sustains the collective credibility of the scientific community. Maintaining research integrity also helps minimise misconduct, such as data fabrication or plagiarism, which can undermine the utility of results.

What might change by 2040?

Looking ahead to 2040, several key drivers are poised to influence research integrity but remain uncertain in their impacts:

1. **Open and transparent science**
   The push for openness in scientific research promotes transparency, accessibility and reproducibility. While it offers benefits, it also presents challenges, including financial pressures on authors due to publication costs and the need to maintain quality and integrity in open-access publications. The Royal Society has been a strong advocate for Open Science, recognising its role in deterring misconduct and promoting research integrity.

   Open science also encompasses a growing emphasis on the publication of different types of outputs, including protocols, null findings, data sets and meta-analyses.

2. **Evolving research culture**
   The research ecosystem is continually evolving, with changes in funding structures, institutional policies and societal expectations. There is a growing emphasis on creating environments that prioritise ethical behaviour, collaboration and accountability over metrics like publication volume or impact factors.

3. **The widespread use of AI in research**
   Data driven technologies are transforming scientific inquiry, enhancing efficiency, accuracy and creativity in research. However, they also introduce challenges related to research integrity, such as ensuring the ethical use of AI, tackling the explainability of AI processes, and maintaining transparency in AI-driven research. The Royal Society's report, *Science in the age of AI*, explores how notions of research integrity are evolving with the integration of AI into scientific research.

Institutional diversity

What is it?

Excellent science takes place in a variety of institutional and industry settings and is supported by a mix of funding modes across the Technology Readiness Level (TRL) scale.

Why does it matter?

Plurality matters for several reasons. First, it ensures a diversity of R&D activity from basic research and discovery through to near market development, creating a broad pipeline of ideas leading to innovations. Second, it builds resilience into the system so we are not reliant on a small and concentrated number of research groups or institutions to deliver discoveries and impact, while avoiding the many downsides that such a monopolistic situation would create. And third, it generates healthy competition and potential for collaboration among groups and institutions where the best, sometimes riskier ideas can come to the fore and be rewarded, and where funding can be competed for from more than one source.

Top-level dynamics of how it might shift

Financial pressures currently facing many institutions could lead to a contraction in certain organisational types, fields and disciplines which policymakers in 2040 may or may not choose to manage. Ongoing fiscal pressures more generally could lead to increased scrutiny and a potentially unrealistic expectation of quick results from (and thus a harmful reduction in) institutions and modes of funding that can deliver transformative scientific and societal impacts over time.

Predictability

What is it?

Science thrives in a stable policy environment that mitigates rather than exacerbates other inherent uncertainties.

Why does it matter?

Predictability in policymaking matters for every part of the science system. It creates not only the underlying conditions for risk taking in scientific inquiry with results that are often highly unpredictable, but also the long-term foundations on which researchers can develop ideas and bodies of knowledge, progressing them further and in new directions. A predictable environment for science and R&D more generally builds the resilience and advisory capacity for tackling existential threats in climate change and biodiversity loss or for managing future shocks and crises. It also instils the confidence among innovators, and those who invest in innovation, to transform the fruits of scientific research into practical solutions.

Top-level dynamics of how it might shift

The last decade of science policy and politics in the UK has been particularly turbulent. Some things that were once considered to be predictable, such as the UK's membership of the EU and related science programmes or, on a smaller scale, its commitment to Official Development Assistance (ODA) research spend, have proven to be anything but. Looking ahead, external risks in everything from populism to hostile states and conflict spillovers remain a significant threat to security in the UK and globally, even if domestic politics continues along a more stable path.

Policy for science, by articulating longer term priorities and spending frameworks, can help mitigate this to some extent, but requires a broad political consensus. This might incorporate building contingencies for different future scenarios in to longer-term plans.

Interdisciplinarity

What is it?

Interdisciplinarity refers to ensuring that the mechanisms exist to enable impactful research and innovation to take place across disciplinary, sector and institutional boundaries.

Why does it matter?

Interdisciplinary research is critical to tackling the complex challenges facing society. Impactful discoveries and innovative solutions often occur at the intersection of disciplines. Working across disciplines and sectors can overcome silos, fostering fresh insights and enhancing collaboration to catalyse impactful and innovative research. Interdisciplinarity is of particular importance in translating science into applied contexts, such as commercially successful businesses or products and processes essential for meeting National Strategy across multiple sectors.

Top-level dynamics of how it might shift

Whilst interdisciplinary research is on the rise and the boundaries between scientific disciplines continue to blur, the UK research and innovation ecosystem remains siloed, negatively impacting the rate and impact of scientific discoveries. Bringing together interdisciplinary teams can be resource-intensive and time-consuming, and interdisciplinary research can be riskier. The increase in emerging technologies such as AI, and the complexity of grand societal challenges is likely to increase the demand for interdisciplinary and innovative solutions over time. To facilitate greater cross discipline working, the research sector will need to consider how funding instruments, institution structures and wider incentives can create a more adaptive and flexible system which brings together the broad range of researcher skills and expertise.

Coherence

What is it?

A coherent system ensures alignment across sectors to enable the free flow of ideas and talent across the research and innovation ecosystem.

Why does it matter?

A coherent and joined-up system ensures flexibility and maximises the resilience of the system. Encouraging collaboration and supporting researcher mobility facilitates the exchange of knowledge and skills. Partnerships and networks across different parts of the research and innovation system can foster more technological breakthroughs and cutting-edge discoveries whilst creating highly skilled individuals that are essential to the future workforce.

Top-level dynamics of how it might shift

Whilst there has been increased recognition of the importance of collaboration and knowledge exchange across institutions, sectors and disciplines in driving impactful research and innovation, progress has been slow. Economic and geopolitical challenges have impacted universities and businesses' ability to build partnerships resulting in a recent decline in university-business collaboration, and hampered movement of researchers between sectors. If the UK higher education sector continues to face increasing financial pressures, this decline is likely to continue.

Enabling regulation and administration

What is it?

Streamlined, efficient and supportive frameworks that facilitate research activities while minimising unnecessary administrative requirements.

Why do they matter?

A bureaucratic system directly influences the efficiency, effectiveness and overall productivity of research activities. Complex and burdensome administrative processes detract from researchers' primary focus of conducting innovative and impactful science. Excessive bureaucracy can also discourage innovation and foster a risk-averse culture and deter international collaboration or investment[81]. However, insufficient bureaucracy can lead to inefficient allocation of resources, non-compliance with regulations, misuse of funds and erosion of public trust in research.

What is changing?

- **Digital platforms**
  The proliferation of disparate digital systems for managing research data and administrative tasks can lead to inefficiencies and increased workloads. There is the potential for this to be improved via better data interoperability between platforms and enhancing user-friendliness.
- **Common protocols**
  There is great potential across the board to harmonise processes, protocols and formats in grant applications, assurance processes and collaboration agreements (eg between UKRI institutions and amongst Universities, Institutes, PSREs, the charity sector, NHS trusts etc). Some specific high value targets should be chosen, and ambitious timetables set with institutional leaders for task and finish groups to deliver common approaches to common issues.
- **Smart Regulation**
  There is an emergent shift towards seeking to use AI to improve some of the issues raised here. Internationally, the European Union's 'Better Regulation' agenda represents efforts to enhance regulatory quality through stakeholder engagement and digital tools for monitoring and evaluation. Similarly, Australia's principles of 'earned autonomy' provide a model where institutions with strong compliance records face reduced oversight.

81 UK Government (2023). Review of research bureaucracy. Available at: https://www.gov.uk/government/publications/review-of-research-bureaucracy (accessed 12 March 2025)

Independence of research

What is it?

Decisions about how funds for scientific research are allocated should be devolved to those with appropriate expertise in the area. At higher TRLs this might be those making industrial or policy decisions, at lower TRLs it is likely to mean active researchers. This ensures that decisions over research are taken by those best placed to judge the scientific viability and benefit of research.

This is sometimes now referred to as the Haldane Principle[82], after a 1918 report chaired by Richard Haldane FBA FRS[83, 84].

Why does it matter?

Expert-led decision-making ensures funding is directed to the most promising areas of inquiry without political interference. The principle laid the foundation for the establishment of independent research councils in the UK, which were tasked with evaluating proposals and distributing resources based on peer review and scientific merit.

How might it evolve?

Conceptions of the relationship between science, society and government priorities continue to evolve. While the Haldane Principle remains a cornerstone of UK science policy, successive governments have interpreted and adapted it to balance autonomy with accountability. The principle has been invoked to justify arms-length governance of funding bodies but also critiqued when political priorities, such as industrial strategy or addressing societal challenges, influence funding decisions. For instance, the formation of UK Research and Innovation (UKRI) in 2018 consolidated research councils under a single body to enhance strategic oversight while maintaining a degree of researcher independence.

This is less about strict separation from political influence and more about achieving a balance. It acknowledges the need for governments to set broad priorities for research aligned with public needs while respecting the autonomy of researchers in determining specific areas of focus. This evolution reflects a dynamic understanding of the principle, ensuring its relevance in a modern context where science is increasingly interdisciplinary, applied and interconnected with societal challenges.

82 The Haldane Principle as defined here does not appear in his 1918 report, and has been variously defined at various times since. We reference this label here given its commonly used modern meaning.

83 Machinery of Government Committee (1918) Report of the Machinery of government committee. Available at: https://wellcomecollection.org/works/y9whjavc (accessed 12 March 2025)

84 Edgarton, D. (2019) Haldane principle's 'centenary' is a good time to bury its myth – Academic freedom needs stronger defences than a made-up principle.

A system inclusive of all

What is it?

An inclusive system ensures that all those working across the research and innovation ecosystem are supported and valued.

Why does it matter?

Creating a system inclusive of all ensures a level playing field so that the research and innovation ecosystem can benefit from the diverse range of talent and expertise who are empowered to operate at their full potential. Supporting individuals at every stage right through from early education to enabling career development and supporting retraining and upskilling is crucial. Some studies also suggest that diverse teams that make use of the skills and experience underrepresented within the broader organisation or field have a distinctive value that can improve long-term outcomes[85].

Top-level dynamics of how it might shift

There has been increasing recognition of the importance of an inclusive and enabling science system. Research assessment frameworks such as the Research Excellence Framework (REF) have evolved over time to increase the scope and recognition of areas outside of traditional research outputs such as publications, including recognition of the research environment and those working across the research workforce. Despite this, many incentive structures continue to recognise only a narrow portion of research activity and tensions remain between reducing the bureaucracy around research and researcher assessment versus engaging in a more qualitative assessment of research. Furthermore, as new technologies and innovations arise there will need to be interventions to support the workforce at every stage to ensure the UK remains agile and responsive to change.

85 Modi N., Lungeanu A., DeChurch L., and Contractor N. (2025) The differential impacts of team diversity as variability versus atypicality on team effectiveness. Scientific reports 15, 4461. Available at: https://www.nature.com/articles/s41598-025-86483-0

International collaboration

What is it?

International collaboration forms the bedrock of science and is enabled by researchers moving between countries and establishing networks and contacts.

Why does it matter?

The diffusion of people and ideas globally is critical not just for knowledge exchange but for extending the impact and reach of scientific discoveries and innovations. That in turn translates into advances in economic performance, the health and security of the planet, and our resilience to national and global-scale shocks.

Top-level dynamics of how it might shift

One of the risks currently facing the UK and other established science nations is rapidly increasing global competition for R&D talent and investment. Another is fragmentation in the geopolitical consensus – the speed and depth of which up to 2040 is hard to predict. Countries that recognise these challenges and take active steps to retain their competitive edge and security, will be better placed than those that take more laissez-faire approaches. By actively facilitating the global diffusion of people and ideas, policymakers can ensure the science base stays at the cutting edge of fields and adapts as new ones emerge. They can ensure a stable and predictable environment for foreign direct investment in R&D intensive industry. They can also exploit global leadership in science and technology in support of soft power and wider foreign policy objectives.

International comparisons to the science system

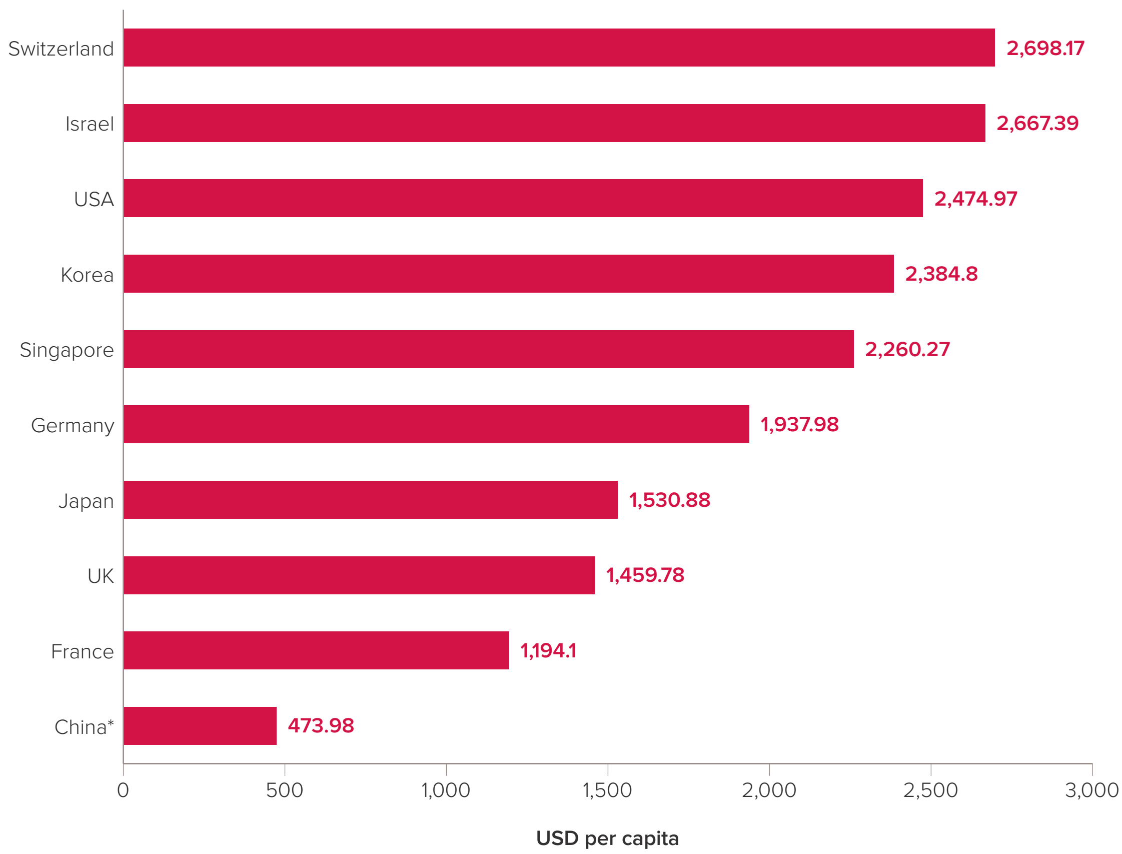
Introduction

This section delves into the research and innovation systems of Germany, Japan, Switzerland and South Korea – four countries selected for their comparable size and economic output to the UK, as well as their seemingly positive approach to science and innovation.

The comparative spend of each of these countries on R&D per head of population is given in Figure 3, alongside some other notable countries[86]. By examining these nations, we aim to uncover valuable insights and best practices that could inform and enhance the UK's own science landscape[87].

FIGURE 3

Total R&D funded per capita, 2021



86 Figures derived from data OECD (GERD) and Worldbank (population).

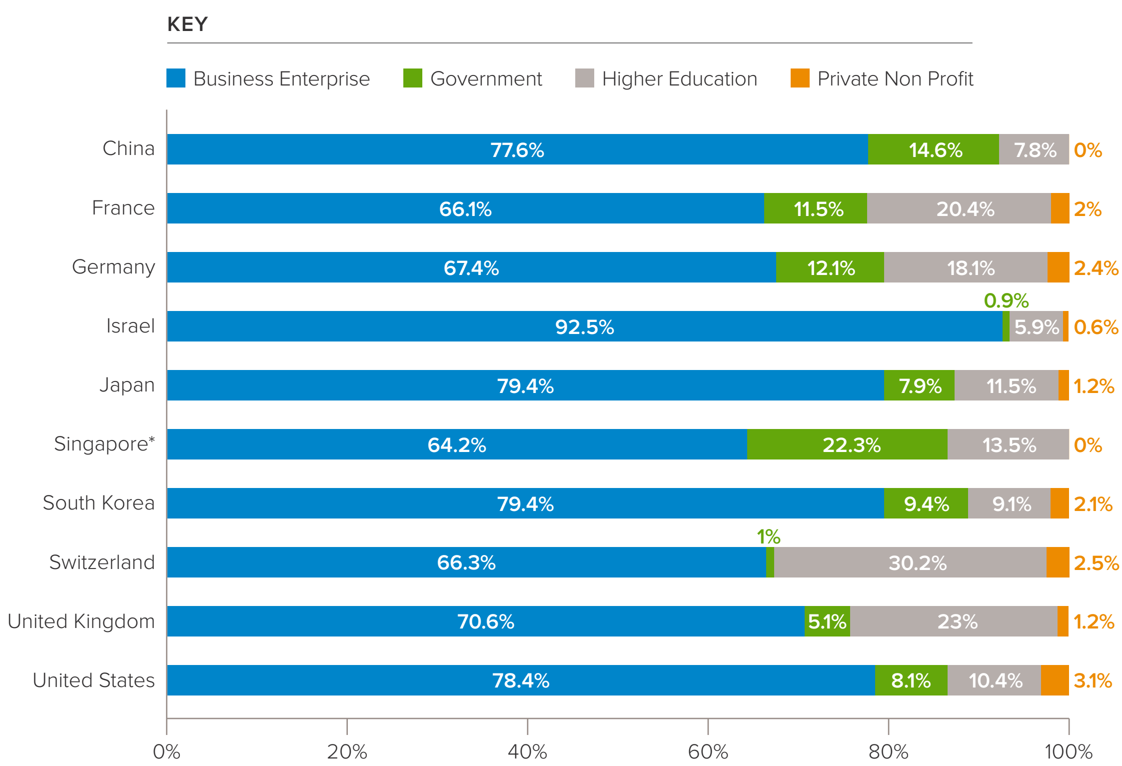
87 GERD data is for 2021 except for Singapore (*) which uses 2020 data. All population and GDP data is for 2021.

Germany, Japan, Switzerland and South Korea each boast robust and dynamic research ecosystems, characterised by strong governmental support, significant investment in R&D, and a culture that values scientific advancement. However, while looking at international comparators is important, there are also limitations of such comparisons in a UK policy context. The structures and systems that emerge in other nations are often deeply rooted in unique social, cultural and historical contexts. Over time, these factors shape the development of research and innovation frameworks that best suit each society's specific needs and circumstances.

Therefore, while we can draw inspiration and lessons from Germany, Japan, Switzerland and South Korea, it is essential to recognise that the UK must tailor its approach to fit its own distinctive context (for example, universities play a very different role in the UK compared to other nations). Figure 4 provides an illustration of the different sectoral makeup of research in these different countries[88].

FIGURE 4

Proportion of R&D performed by each sector, 2021



88 OECD. (2024) Research and Development Statistics.

89 Data is for 2021 except for Singapore (*) which uses 2020 data.

Long term investment and policy planning

Germany's long term science policy is primarily guided by the High Tech Strategy 2025[90] and the Federal Report on Research and innovation 2024[91]. The High-Tech Strategy outlines twelve key missions and a vision for enhancing Germany's global competitiveness, whilst the Federal Report on Research and innovation 2024 provides an overview of progress in regard to research and innovation policies and outputs. Both emphasise the ambition to increase R&D investment to 3.5% of GDP by 2025.

The overarching approach in Japan is outlined in their Sixth Science, Technology and Innovation Basic Plan (STI Basic Plan)[92], and the Integrated Innovation Strategy[93]. The STI Basic Plan outlines Japan's long term vision over a five year period, whereas the Integrated innovation strategy (renewed yearly) aims to implement the goals and objectives set out in the STI Basic Plan through specific measures and initiatives. Japan's overarching target for spend on R&D is set at 4% by the end of the 6th STI Basic Plan period, which is fiscal year 2025.

Switzerland has three key strategies regarding science, research and innovation: the Federal Council's Science, Technology and Innovation (STI) Working Programme 2024 – 2027[94]; the Swiss National Science Foundation (SNSF) Multi-Year Funding Programme 2025 – 2028[95]; and the Swiss Science Council (SSC) Mission-oriented Research and Innovation in Switzerland report[96]. The STI working programme aims to outline priorities and challenges, whilst the SNSF multi-year funding programme is an overview of the approach to supporting and funding research over the allotted period. The SSC report is designed to address predefined societal challenges via a mission-oriented approach. Switzerland does not set a specific target for R&D spend.

90 The Federal Government [of Germany]. (2018). Federal Government Report on the High-Tech Strategy 2025. Available at: https://www.bmbf.de/SharedDocs/Publikationen/DE/FS/657232_Bericht_zur_Hightech-Strategie_2025_en.pdf?__blob=publicationFile&v=2 (accessed 12 March 2025)

91 Federal Ministry of Education and Research (2024). Federal Report on Research and Innovation 2024. Available at: https://www.bundesbericht-forschung-innovation.de/files/BMBF_BuFI-2024_Short-version.pdf (accessed 12 March 2025)

92 Government of Japan. (2021). Science and Technology Basic Plan. Available at: https://www8.cao.go.jp/cstp/english/sti_basic_plan.pdf (accessed 12 March 2025)

93 Government of Japan. (2024). Integrated Strategy 2024. Available at: https://www8.cao.go.jp/cstp/tougosenryaku/togo2024_honbun_eiyaku.pdf (accessed 12 March 2025)

94 Swiss National Science Foundation (2024). Arbeitsprogramm 2024-2027. Available at: https://s3.eu-central-2.wasabisys.com/swr-cms/d/assets/veroeffentlichungen/2024_10_swr_arbeitsprogramm-2024-2027_dfie.pdf (accessed 12 March 2025)

95 Swiss National Science Foundation (2025). Mehrjahresprogramm 2025-2028. Available at: https://www.snf.ch/media/en/uHnRwXS9FpfgQ58G/SNF-Mehrjahresprogramm_2025-2028_en.pdf (accessed 12 March 2025)

96 Swiss Science Council (2023). Mission-oriented Research and Innovation in Switzerland. Available at: https://s3.eu-central-2.wasabisys.com/swr-cms/d/assets/legacy/stories/pdf/en/SSC_2023_Report_Mission-orientedResearchAndInnovationInSwitzerland.pdf (accessed 12 March 2025)

South Korea's long-term science, research and innovation strategies include the Fifth Science and Technology Master Plan (2023 – 2027)[97], which aims to strengthen national R&D strategies and foster an innovative ecosystem; the Science and Technology Future Strategy 2045[98], which sets a vision for enhancing quality of life, promoting economic growth, and addressing key challenges; and the Special Act on the Fostering of Critical and Emerging Technologies[99], which focuses on strategic investment and development. The Science and Technology Future Strategy sets a target of 5% GDP investment in R&D by 2045.

Education and skills

Germany emphasises early educational sorting and vocational education and training (VET). The dual system combines vocational schools and company training, with about 50% of school-leavers undergoing vocational training[100]. The revised Vocational Training Act of 2020 introduced new designations to equate vocational and academic education[101].

Germany also offers numerous funding programmes for early career PhD students and supports diverse research opportunities through its broad research landscape[102]. Germany perhaps has the most extensive offering for PhD students due to its larger network of scholarships and institutions, including opportunities like the German Academic Exchange Service (DAAD) scholarships[103] (offered to international students), research grants from institutions like the Max Planck Society and the Helmholtz Association, and numerous university-specific funding options.

Switzerland places a strong emphasis on both academic and vocational education. Like Germany, it also has a VET system, which comes after compulsory schooling (age 15 or 16). The Swiss VET system operates on a dual model, combining workplace training with classroom instruction, and offers pathways to higher education through the Federal Vocational Baccalaureate (around two-thirds of young people study via the VET system)[104]. Switzerland's higher education system includes ten cantonal universities and two federal institutes of technology (ETH Zurich and EPFL).

97 Ministry of Science and ICT. [of South Korea] (n.d.). Press release of "The Fifth Science and Technology Master Plan (2023-2027)". Available at: https://www.msit.go.kr/eng/bbs/view.do?sCode=eng&mId%20=4&mPid=2&pageIndex=&bbsSeqNo=42&nttSeqNo=762&searchOpt=ALL&searchTxt (accessed 12 March 2025)

98 STIP compass (2021). Policy Initiatives for 2021. Available at https://stip.oecd.org/stip/interactive-dashboards/policy-initiatives/2021%2Fdata%2FpolicyInitiatives%2F99991589 (accessed 12 March 2025)

99 Korea Legislation Research Institute. (2023). Act on the Promotion of Science and Technology. Available at: https://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=62878&type=part&key=18 (accessed 12 March 2025)

100 Federal Institute for Vocational Education and Training. (n.d.). Vocational education and training in Germany. Available at: https://www.bibb.de/en/77203.php (accessed 12 March 2025)

101 Federal Ministry of Education and Research. (n.d.). The new Vocational Training Act. Available at: https://www.bibb.de/dokumente/pdf/bmbf_The_new_Vocational_Training_Act.pdf (accessed 12 March 2025)

102 Research in Germany. (n.d.). Funding programmes for PhD students. Available at: https://www.research-in-germany.org/en/your-goal/phd/funding-programmes.html (accessed 12 March 2025)

103 German Academic Exchange Service (n.d.). DAAD scholarships. Available at: https://www.daad.de/en/studying-in-germany/scholarships/daad-scholarships/ (accessed 12 March 2025)

104 Eurydice. (n.d.). Organisation of vocational upper secondary education in Switzerland. Available at: https://eurydice.eacea.ec.europa.eu/national-education-systems/switzerland/organisation-vocational-upper-secondary-education (accessed 12 March 2025)

The Swiss National Science Foundation (SNSF) provides various grants[105], and universities like ETH Zurich and EPFL offer their own scholarships and funding options. Switzerland also offers the Swiss Government Excellence Scholarships[106], which cover tuition, living expenses and health insurance for international PhD students.

Japan provides both academic and vocational routes into science careers. Institutions like KOSEN offer five-year programmes starting from age 15, focusing on practical and technical skills. Senmon Gakko (vocational schools) emphasise practical skills, while universities and junior colleges offer traditional higher education paths. The Japanese government has initiatives like the Top Global University Project[107], which grants additional funding to universities to enhance their international connections. PhD students can benefit from various scholarships, including the MEXT Scholarship, which covers tuition fees and living expenses for international students[108].

South Korea focuses on integrating technology into education and promoting STEM education through initiatives like STEAM (Science, Technology, Engineering, Arts and Mathematics)[109]. The country has implemented digital transformation in education, with platforms like e-Hakseupteo supporting remote learning. South Korea provides several scholarship opportunities to domestic and international students, including the Global Korea Scholarship (GKS) which provides full funding, including tuition, living expenses and airfare for international students[110].

Plurality of institutions and funding

Germany has over 1,000 publicly funded research institutions, categorised into several key organisations. The Fraunhofer-Gesellschaft focuses on applied research, with two-thirds of its budget coming from contract research revenue[111], amounting to 2.9 billion euros in 2022[112]. The Max-Planck-Gesellschaft has a focus on basic research, with 88% of its 2.3 billion euro budget in 2021 coming from public funding[113].

105 Swiss National Science Foundation. (n.d.). Find a funding scheme. Available at: https://www.snf.ch/en/A7fep1lPxz1XezVS/page/find-funding-scheme (accessed 12 March 2025)

106 State Secretariat for Education, Research and Innovation. (n.d.). Swiss Government Excellence Scholarships. Available at: https://www.sbfi.admin.ch/sbfi/en/home/education/scholarships-and-grants/swiss-government-excellence-scholarships.html (accessed 12 March 2025)

107 Ministry of Education, Culture, Sports, Science and Technology (n.d.). Top Global University Project. Available at: https://www.mext.go.jp/en/policy/education/highered/title02/detail02/sdetail02/1395420.htm (accessed 12 March 2025)

108 Ministry of Education, Culture, Sports, Science and Technology (n.d.). Support System to foreign students. Available at: https://www.mext.go.jp/en/policy/education/highered/title02/detail02/sdetail02/1373897.htm (accessed 12 March 2025)

109 Nam-Hwa Kang (2019). A review of the effect of integrated STEM or STEAM (science, technology, engineering, arts, and mathematics) education in South Korea. Available at https://apse-journal.springeropen.com/articles/10.1186/s41029-019-0034-y (accessed 12 March 2025)

110 GKS Scholarship (n.d.). Scholarship information. Available at https://gksscholarship.com (accessed 12 March 2025)

111 UK Government (2024) UK Science and Innovation Network summary: Germany. Available at: https://www.gov.uk/government/publications/uk-science-and-innovation-network-country-snapshot-germany/uk-science-and-innovation-network-summary-germany (accessed 12 March 2025)

112 Federal Ministry of Education and Research (n.d.). Fraunhofer-Gesellschaft – Research in Germany. Available at: https://www.research-in-germany.org/en/research-landscape/research-institutions/fraunhofer-gesellschaft.html (accessed 12 March 2025)

113 Federal Ministry of Education and Research (n.d.). Max Planck Society: Leaders in Scientific Research. Available at: https://www.research-in-germany.org/en/research-landscape/research-institutions/max-planck-gesellschaft.html (accessed 12 March 2025)

The Helmholtz Association operates 18 research centres, focusing on six key research fields and managing large-scale research infrastructures with a 2021 budget of 5.4 billion euros[114]. The Leibniz Association supports 97 research institutions with a focus on societal and international relevance, funded by federal and state governments with a 2021 budget of 2.1 billion euros[115]. Germany's higher education institutions, including universities of applied sciences, are globally recognised, with initiatives like the Excellence Strategy enhancing their research capabilities[116]. Additionally, Germany has 44 federal research institutions and nearly 140 state-level institutions focusing on policy-relevant research[117].

Japan's research landscape is supported by four main funding agencies: the Japan Society for the Promotion of Science (JSPS)[118], which provides competitive grants and fellowships; the Japan Science and Technology Agency (JST)[119], which implements national science policies; the Japan Agency for Medical Research and Development (AMED)[120], which funds medical R&D; and the New Energy and Industrial Technology Development Organisation (NEDO)[121], which promotes industrial technology R&D. There are several other additional institutions that add to the plurality of Japan's research landscape such as The World Premier International Research Centre Initiative (WPI)[122], RIKEN[123], the National Institute of Natural Sciences[124], and Kosetsushi centres[125]. As of 2023, Japan has 86 national universities, 102 public universities and 622 private universities, along with 27 national research institutions.

114 Federal Ministry of Education and Research (n.d.). Helmholtz Association: Advancing German Research. Available at: https://www.research-in-germany.org/en/research-landscape/research-institutions/helmholtz-association.html (accessed 12 March 2025)

115 Federal Ministry of Education and Research (n.d.). Leibniz Association: Pioneering German Research Institutes, https://www.research-in-germany.org/en/research-landscape/research-institutions/leibniz-association.html (accessed 12 March 2025)

116 Federal Ministry of Education and Research (n.d.). Germany's Universities: Comprehensive Guide and Insights. https://www.research-in-germany.org/en/research-landscape/university-landscape.html (accessed 12 March 2025)

117 Federal Ministry of Education and Research (n.d.). Federal institutions – Research in Germany. [online] Available at: https://www.research-in-germany.org/en/research-landscape/research-institutions/federal-institutions.html (accessed 12 March 2025)

118 JSPS (n.d.). Japan Society for the Promotion of Science. Available at: https://www.jsps.go.jp/english/ (accessed 12 March 2025)

119 Japan Science and Technology Agency (n.d.). Japan Science and Technology Agency. Available at: https://www.jst.go.jp/EN/ (accessed 12 March 2025)

120 Japan Agency for Medical Research and Development (n.d.). What's new. Available at: https://www.amed.go.jp/en/ (accessed 12 March 2025)

121 NEDO (n.d.). New Energy and Industrial Technology Development Organization. Available at: https://www.nedo.go.jp/english/ (accessed 12 March 2025)

122 JSPS (n.d.). World Premier International Research Center Initiative (WPI). Available at: https://www.jsps.go.jp/english/e-toplevel/ (accessed 12 March 2025)

123 RIKEN (n.d.). About RIKEN. Available at: https://www.riken.jp/en/about/ (accessed 12 March 2025)

124 National Institutes of Natural Sciences (n.d.). National Institutes of Natural Sciences Website. Available at: https://www.nins.jp/en/ (accessed 12 March 2025)

125 CEPR (2016). Roles of Japan's local public technology centres in SME innovation. Available at: https://cepr.org/voxeu/columns/roles-japans-local-public-technology-centres-sme-innovation (accessed 12 March 2025)

These institutions are under various ministries and support open innovation to meet national and societal needs.

Switzerland's research institutions include the Swiss Federal Institutes of Technology (ETH Domain)[126], comprising ETH Zurich, EPFL, and four research institutes (PSI, WSL, Empa and Eawag). These institutions focus on high-quality education, cutting-edge research, and industry collaboration. The Swiss National Science Foundation (SNSF)[127], the Swiss Academies of Arts and Sciences, and Innosuisse promote research and innovation, with international collaborative calls advertised by SNSF and Innosuisse[128]. Swiss universities and universities of applied sciences conduct both basic and applied research, with a strong emphasis on practical applications and industry collaboration.

South Korea's research landscape is supported by the National Research Foundation of Korea (NRF)[129], which funds basic research in science and engineering, humanities and social sciences, and national strategic R&D programmes. The NRF also facilitates international cooperation and academic research. South Korea's top universities, such as Seoul National University and KAIST, are known for their research excellence, particularly in STEM fields.

The country has implemented various initiatives to boost R&D, including the Korean Government Scholarship Program (KGSP) and the KAIST Graduate Scholarship, which provide substantial funding for PhD students.

Innovation

Germany's R&D spending has grown continuously and more than doubled in the past 20 years, with R&D spending amounting to 3.1% of GDP in Germany in 2022[130]. As a particular feature of the German system, domestic industry plays an important role, with private sector R&D accounting for roughly two thirds of overall R&D spending. According to the 2021 EU R&D Investment Scoreboard, 12 of the top twenty most active European R&D companies were located in Germany (including Volkswagen, Daimler, BMW, Robert Bosch)[131]. Although large companies contribute most to domestic spending in R&D (2022: €82 billion, +8% from 2021), German SMEs spent about 9% of investments made by the private sector. The German Research Allowance Act (Forschungszulagengesetz or FZulG), introduced in 2019, provides a federal R&D subsidy[132].

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126 ETH Board (2023). The ETH Domain, an essential component of the Swiss model for success – ETH-Rat. Available at: https://ethrat.ch/en/eth-domain/the-eth-domain-an-essential-component-of-the-swiss-model-for-success/ (accessed 12 March 2025)

127 Swiss National Science Foundation (2024). Get a grant. Available at: https://www.snf.ch/en/ORgUpoSFePiH6QCp/page/get-a-grant (accessed 12 March 2025)

128 Swiss Innovation Agency (2024). Funding for international projects. Available at: https://www.innosuisse.admin.ch/en/funding-for-international-projects (accessed 12 March 2025)

129 NRF (n.d.). Basic Research in Science & Engineering : National Research Foundation of Korea, https://www.nrf.re.kr/eng/page/69ededa4-9334-4b9c-8984-5d04d2f69222 (accessed 12 March 2025)

130 OECD Data (n.d) Gross domestic spending on R&D. Available at: https://www.oecd.org/en/data/indicators/gross-domestic-spending-on-r-d.html?oecdcontrol-8027380c62-var3=2021 (accessed 17 April 2025)

131 European Commission (2021). The 2021 EU Industrial R&D Investment Scoreboard. Available at: https://iri.jrc.ec.europa.eu/scoreboard/2021-eu-industrial-rd-investment-scoreboard (accessed 12 March 2025)

132 PWC (n.d.). Germany – Corporate – Tax Credits and Incentives. Available at: https://taxsummaries.pwc.com/germany/corporate/tax-credits-and-incentives (accessed 12 March 2025)

Under this act, companies and entrepreneurs can apply for a tax-free subsidy of up to 25% of eligible R&D expenses, with a maximum limit of 1 million euros per year until June 2026[133]. This amount can be higher for small and medium-sized enterprises.

According to the results of the Survey of Research and Development which was published by the Statistics Bureau of Japan in December 2023, Japan's total expenditure on R&D in FY2022 rose to a record high ¥20.70 trillion (£108 billion)[134]. Expenditure on R&D as a percentage of GDP was 3.65%. A large portion (73.1%) of Japan's R&D expenditure comes from the private sector. Business enterprises invested ¥15.13 trillion (£78.8 billion) in R&D expenditure in FY2022, a 6.4% increase on the previous year. Universities accounted for 18.6%, investing ¥3.84 trillion (£20 billion) with a 1.5% increase on the previous year. Japan's tax credit system allows private companies to deduct a percentage of their R&D expenses from their corporate tax payments. The tax credit rate varies depending on the type and amount of R&D expenditure, with a general rate of 8% to 10% for total R&D expenses[135].

There are also additional incentives for specific types of research, such as joint research with universities or national research institutes[136].

In 2021, Switzerland invested over 20 billion USD in research and development annually, which equates to 3.3% of GDP[137]. The private sector is a major contributor to R&D in Switzerland, investing a total of CHF 15.5 billion (2.1% of GDP) in 2019. Three-quarters of this funding went to R&D-intensive sectors: the pharmaceuticals and chemical industry (36.7%), metals industry (13.7%), research laboratories (13%) and new technologies (11.3%). Switzerland offers tax incentives for R&D, primarily at the cantonal level. These incentives include an additional R&D deduction and a patent box regime. The additional R&D deduction allows companies to deduct up to 50% of their actual R&D expenses, depending on the canton[138]. The patent box regime reduces corporate income tax on income derived from qualifying patents by up to 90%, also varying by canton[139].

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133 Warth & Klien Grant Thornton (2021). German Act on Tax Incentives for Research and Development (FZulG). Available at: https://www.grantthornton.de/globalassets/1.-member-firms/de-germany/pdf-download/fzulg_warth_klein_grant_thornton.pdf (accessed 12 March 2025)

134 UK Government (2024) UK Science and Innovation Network summary: Japan. Available at: https://www.gov.uk/government/publications/japan-uk-science-and-innovation-network-summary/uk-science-and-innovation-network-summary-japan (accessed 12 March 2025)

135 PWC (n.d.). Japan – Corporate – Tax Credits and Incentives. Available at: https://taxsummaries.pwc.com/japan/corporate/tax-credits-and-incentives (accessed 12 March 2025)

136 INNOTAX (2023). Open innovation activity-based R&D tax credit. Available at: https://stip.oecd.org/innotax/incentives/JPN2 (accessed 12 March 2025)

137 Swiss Government (n.d.). Research and Development. Available at: https://www.eda.admin.ch/aboutswitzerland/en/home/wirtschaft/uebersicht/forschung-und-entwicklung.html (accessed 12 March 2025)

138 KPMG (2021). Tax Incentives for R&D in Switzerland. Available at: https://assets.kpmg.com/content/dam/kpmg/pdf/2016/04/ch-tax-incentives-for-rd-in-switzerland-en.pdf (accessed 12 March 2025)

139 PWC (n.d.). Switzerland – Corporate – Tax Credits and Incentives. Available at: https://taxsummaries.pwc.com/switzerland/corporate/tax-credits-and-incentives (accessed 12 March 2025)

In 2023, domestic R&D spending in South Korea reached KRW 119.74 trillion, making up 4.96% of GDP[140]. Government spending on R&D amounted to 23.6% of total spend, whilst foreign funds and the private sector made up the other 76.4%. Companies in South Korea can benefit from tax credits for R&D expenditures, including a general tax credit and additional credits for investments in R&D equipment[141]. Recent enhancements have introduced a phased approach to these tax credits, aiming to support both large corporations and small and medium-sized enterprises (SMEs).

Implications for science policy in the UK

The elements of the systems at play in comparable nations are a consequence of specific historical and cultural contexts, just as is the case in the UK. Yet there are many similarities between the UK and the comparator countries.

Each nation sets out priorities and/or missions that aim to set an overall vision for science, research and infrastructure. There is a plurality of institutions and funding types across all nations, including in the UK, though Germany does stand out in this regard. There is a will to stimulate innovation and growth via science and technology, and ambitions to work with industry to boost R&D outputs. All nations offer a variety of opportunities to PhD students (though some more than others), with programmes for international students as well. It is ultimately in the details of how these overarching goals and ambitions are administered and achieved that can define the success of a particular nations system.

The level of investment will continue to be a key determining factor in a nations ability to deliver, and the difference in overall percentage of GDP spent on R&D is notable when comparing the UK to these other four nations. Additionally, the spending targets set out by Germany, Japan, and South Korea are all more ambitious than the UK's.

How the UK achieves its aims regarding research and innovation will be down to how well it can understand its own history and culture, and lean into the positives of this while reducing the negatives. This requires a broad set of principles that can be adhered to and supported across parliament, and a set of ambitious policies that are implemented effectively.

140 Jihae L. (2024). Domestic R&D Spending as % of GDP Ranked No. 2 in 2023. Available at: https://www.korea.net/NewsFocus/Sci-Tech/view?articleId=264121 (accessed 12 March 2025)

141 PWC (n.d.). South Korea – Corporate – Tax Credits and Incentives. Available at: https://taxsummaries.pwc.com/republic-of-korea/corporate/tax-credits-and-incentives (accessed 12 March 2025)

Part two

Key issues for a long-term vision for science to address

Left
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Skills

A vision for careers and skills

A high performing science system requires people with a wide range of skills, qualifications and experience[142]. Science and innovation underpin the modern economy, and there is broad agreement across the political spectrum that skills are critical for economic growth[143, 144]. Whilst this is understood by policymakers, there remain significant barriers to enabling the people within the system to thrive. The lack of joined-up thinking for post-16 education provision results in a complicated and incoherent offer for learners and employers, with individuals not proceeding directly to a university at a particular disadvantage[145]. There is insufficient permeability of ideas, people and technologies across sectors[146]. Visa costs in the UK remain significantly higher than other leading science nations[147]. Interdisciplinarity is increasingly important for scientists finding solutions to global challenges[148], but poorly catered for in research policy. And while team science has become increasingly common across all fields of research, the way in which the researchers are recognised generally fails to capture the contributions of all those involved, raising questions around recognition and the adequacy of current incentives[149].

The UK is also hampered by significant differences in skills supply and demand across its nations and regions, and has various models for education and curriculum, funding for higher education and training which face their own challenges.

Long-term strategy and joined-up policymaking are critical to transforming the skills landscape and enabling the workforce to deliver their potential. The emergence of a move towards a more holistic approach to policy can be seen with the creation of Skills England. This needs to be matched by policies to ensure the system is coherent, predictable, agile and inclusive as well as effectively linked to skills agendas across all four nations of the UK.

142 Royal Society (2024). Science and the economy. Available at: https://royalsociety.org/news-resources/publications/2024/science-and-the-economy/ (accessed 12 March 2025)

143 Royal Society (2024). Science and the economy. Available at: https://royalsociety.org/news-resources/publications/2024/science-and-the-economy/ (accessed 12 March 2025)

144 UK Parliament (2024). Importance of skills: Economic and social benefits. Available at: https://lordslibrary.parliament.uk/the-importance-of-skills-economic-and-social-benefits/ (accessed 12 March 2025)

145 HEPI (2023). Connecting the Dots – The Need for an Effective Skills System in England. Available at: https://www.hepi.ac.uk/2023/11/23/26086/ (accessed 12 March 2025)

146 UK Government (2021). Research, development and innovation (RDI) organisational landscape: an independent review. Available at: https://www.gov.uk/government/publications/research-development-and-innovation-organisational-landscape-an-independent-review (accessed 12 March 2025)

147 Royal Society (2019). UK science and immigration: why the UK needs an internationally competitive visa offer. Available at: https://royalsociety.org/news-resources/publications/2019/uk-science-and-immigration-why-the-uk-needs-an-internationally-competitive-visa-offer/ (accessed 12 March 2025)

148 NCUB (2023). Diverse researcher career pathways will power UK innovation and growth, say business and university leaders. Available at: https://www.ncub.co.uk/insight/diverse-researcher-career-pathways-will-power-uk-innovation-and-growth-say-business-and-university-leaders/ (accessed 12 March 2025)

149 Academy of Medical Sciences. Team science. Available at: https://acmedsci.ac.uk/policy/policy-projects/team-science (accessed 12 March 2025)

BOX 2

Education is devolved across the four nations of the UK

The four nations of England, Scotland, Wales and Northern Ireland each run their own education systems and whilst the systems in Wales and Northern Ireland are broadly similar to the English system, Scotland differs in several aspects.

Whilst the recommendations in this section focus primarily on the government in Whitehall, we refer to English regions and Devolved Administrations where appropriate.

Compulsory education

While the school leaving age in England is 16, students must remain in official education or training until the age of 18. Wales, Northern Ireland and Scotland have a compulsory schooling age up to 16.

Principles for the future

Here we set out the principles for a future 2040 skills system, applying some of those laid out previously in this report. These include a system that is coherent; predictable and agile; and inclusive.

A system that is coherent

1. **There is coherence and alignment across the skills ecosystem.**
   Future skills demand is anticipated and acted on by providing high-quality education through a balanced curriculum. Pupils are supported throughout their education journey through a flexible system which accommodates differences in development. For those in the workforce, ample training opportunities for adult upskilling and retraining are provided. A comprehensive approach to the skills ecosystem and workforce development is linked to government industrial strategy. Within this context, the importance of Place is considered so that local needs are considered when thinking about local training and employment opportunities, with funding to accompany those needs.

A system that is predictable and agile

2. **The skills landscape is supported by predictable and consistent policymaking.**
   The policy landscape is predictable with consistent signals from government. Government priorities remain stable, and policies are communicated clearly. As a result, there is progress on government missions, and significant capacity is built up across the workforce in these areas. Advances in science lead to improved productivity, growth and wellbeing. The UK is a leader across critical sectors such as clean energy, digital technologies and life sciences.

3. **The system is agile and responsive.** Whilst ensuring progress against the government missions, the ecosystem readily adapts to new innovations, technologies and challenges. The workforce is agile, with opportunities for adult learning and upskilling, supported by public funding and private sector investment. Alongside gaining subject-based knowledge and specialist expertise, the workforce is trained in essential skills.

4. **Workforce mobility is supported across sectors, disciplines and borders.** Mobility of the workforce is supported by a system that enables individuals to move and work across sectors and disciplines. The UK research and innovation ecosystem is globally competitive and supports international mobility through reduced barriers to movement. The UK attracts and retains talent. Skills and knowledge are shared across those working within the R&D system, both in the UK and abroad.

A system that is inclusive

5. **The system is inclusive and those working across the research and innovation ecosystem are supported.** Organisations and individuals working across the research and innovation ecosystem facilitate a positive research culture. Those working in leadership support the development of the workforce. Those working across the education and skills ecosystem are cognisant of diversity and inclusion, and everyone, in every role, is valued. There are opportunities for stable career progression. Whilst the importance of individual excellence and vision is recognised, there are appropriate incentives to ensure recognition of the broad range of ways in which research and development are undertaken, and teamwork is championed.

Challenges for the UK ecosystem

The key challenges that need to be overcome to reach the vision for 2040 are summarised below.

Shortage of suitably qualified specialist teachers in key subjects and limited resourcing to support an effective R&D system

If not addressed, a lack of resourcing will continue to reduce the UK's capacity to deliver high-quality education in STEM subjects. There has been an ongoing shift away from the more interactive and resource-intensive forms of science practical work[150], and a persistent failure to meet teacher recruitment targets in key STEM subjects such as chemistry, maths and physics has resulted in a shortage of suitably qualified teachers in STEM[151]. This has resulted in secondary school pupils being taught by teachers teaching outside their specialism[152]. Challenges around specific subjects are evident.

In physics, approximately 27% of teaching hours were taught by teachers with no relevant post-A-level qualifications[153], and in maths, less than a third of state-funded schools and colleges were offering the Core Maths qualification as a subject, and only 7% of A-level students not taking A-level maths were found to be taking the alternative Core Maths qualification[154]. There are also other persistent challenges such as the uneven regional distribution of specialist teachers[155].

Teachers play a key role in supporting young people to achieve their career aspirations and recruiting and retaining high-quality STEM teachers is seen as vital to boosting the UK's future STEM workforce[156]. Indeed, between 2019 and 2023 one study found that young people were becoming less interested in science and computing, with the decline in interest being more pronounced amongst younger cohorts[157]. Alongside teachers, family – and especially parents – were seen as influential in shaping young people's education and career choices; students with family members who worked in areas relating to STEM were more likely to take up STEM subjects[158].

150 Royal Society (2023). Science Education Tracker 2023. Available at: https://royalsociety.org/news-resources/projects/science-education-tracker/ (accessed 12 March 2025)

151 Department for Education (2019). Initial Teacher Training (ITT) Census for 2019 to 2020, England. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/848851/ITT_Census_201920_Main_Text_final.pdf (accessed 12 March 2025)

152 Royal Society (2014). Vision for science and mathematics education. Available at: https://royalsociety.org/topics-policy/projects/vision/ (accessed 12 March 2025)

153 Ofsted (2021). Research review series: science. Available at: https://www.gov.uk/government/publications/research-review-series-science/research-review-series-science (accessed 12 March 2025)

154 Royal Society (2023). Lack of Core Maths provision fails students, says the Royal Society. Available at: https://royalsociety.org/news/2023/12/core-maths-provision/ (accessed 12 March 2025)

155 House of Commons Education Committee (2024). Teacher recruitment, training and retention Second Report of Session 2023–24. Available at: https://committees.parliament.uk/publications/44798/documents/222606/default/ (accessed 12 March 2025)

156 Teach First (2024). UK STEM skills shortage 'at risk of growing' as low-income parents fear for children's prospects. Available at: https://www.teachfirst.org.uk/press-release/uk-stem-skills-shortage (accessed 12 March 2025)

157 Hamlyn B., Brownstein L., Shepherd A., Stammers J, Lemon (Verian) C (2024). Science Education Tracker 2023. Available at: https://royalsociety.org/-/media/policy/projects/science-education-tracker/science-education-tracker-2023.pdf (accessed 12 March 2025)

158 Hamlyn B., Brownstein L., Shepherd A., Stammers J, Lemon (Verian) C (2024). Science Education Tracker 2023. Available at: https://royalsociety.org/-/media/policy/projects/science-education-tracker/science-education-tracker-2023.pdf (accessed 12 March 2025)

These family connections to STEM were found to be more concentrated among students from advantaged backgrounds, further perpetuating inequalities in access to STEM.

Alongside pay, workload and retention there are also challenges around the multitude of routes into teaching[159], and professional development of teachers. An independent review of teachers' professional development found that whilst both the Early Career Framework (ECF) and National Professional Qualifications (NPQs) were well-regarded by participants, there were still challenges around teachers not receiving a high-quality teacher development offer, inconsistent implementation and workload pressures[160]. Charities such as Now Teach have enabled additional teaching capacity by supporting mid/late-career stage individuals who wish to undergo a career change into teaching. Whilst these initiatives are positive, systematic change to address the teaching shortages is still needed. There are also persistent retention and recruitment challenges facing the Further Education (FE) sector specifically. The Augur review of post-18 education and funding back in 2019 highlighted the financial decline that the FE sector has faced[161].

The difference in funding between schools and colleges has led to a widening pay gap between those teaching in Further Education and those in schools[162]. This is exacerbated further by the fact that many of the lecturers in FE are able to take much better paid posts in industry.

Early specialisation and narrowness of curriculum

The scope and application of mathematics and data has undergone a rapid expansion over the past fifty years, driven by an increase in data availability, computing capabilities and statistical methodologies. Despite this, the early specialisation and narrowness of the curriculum for 16- to 18-year-olds results in a loss of talent with many young people leaving education with limited science and maths skills. There are also particular challenges for those failing high stakes exams leading to long term consequences for the individual. Students who only just fail to achieve the required threshold for national examinations taken at the end of compulsory education in England have a lower probability of entering an upper-secondary education and are more likely to drop out at age 18 without employment[163].

159 Kernohan (2023). What is going on with initial teacher training in higher education. Available at: https://wonkhe.com/blogs/what-is-going-on-with-initial-teacher-training-in-higher-education/ https://wonkhe.com/blogs/what-is-going-on-with-initial-teacher-training-in-higher-education/ (accessed 12 March 2025)

160 Ofsted (2024). Independent review. Teachers' professional development in schools. Available at: https://www.gov.uk/government/publications/teachers-professional-development-in-schools (accessed 12 March 2025)

161 Department for Education (2019). Post-18 review of education and funding: independent panel report. Available at: https://assets.publishing.service.gov.uk/media/5ceeb35740f0b62373577770/Review_of_post_18_education_and_funding.pdf (accessed 12 March 2025)

162 NCFE (2023). Sector Spotlight: Further Education. Available at: https://www.ncfe.org.uk/media/0q5bp2ad/175-sector-spotlight-reports-further-education.pdf (accessed 12 March 2025)

163 Machin S, McNally S, Ruiz-Valenzuela J (2020). Entry through the narrow door: The costs of just failing high stakes exams. Available at: https://cep.lse.ac.uk/_NEW/PUBLICATIONS/abstract.asp?index=7341 (accessed 12 March 2025)

A balanced curriculum is needed to ensure that young people continue studying science and mathematics up to age 18 and leave education scientifically and numerically literate[164, 165]. Reforming the secondary education system to introduce a broader range of study post-16 such as a baccalaureate-style structure, like many international education systems, would enable learners to study a wider range of subjects and seek to end the 'illusion of choice'.

Lack of support and recognition of Further Education and vocational routes

The House of Lords report on the Economics of Post-School Education concluded that there was a lack of support for post-16 education options such as vocational qualifications and apprenticeships[166]. The changes to university financing incentivises universities to attract prospective students onto undergraduate degrees. This coupled to a lack of information on alternative routes and schools incentivised to send pupils down the academic route, have led to an unbalanced system in favour of this one route of progression. In addition, employers often use degrees as a screening device for applicants regardless of the requirements of the position. Notably, there has been a significant decline in the uptake of alternative options; those starting apprenticeships fell by 33.8% between 2015 – 16 and 2022 – 23[167].

An independent evaluation of T-levels highlighted several issues with the vocational qualification including poor value to students, lack of appropriate work placement or training options and high student dropout rates[168]. T-levels require a substantive amount of industry time and are hard to provide unless there is industry backing. There are also regional inequalities, with many parts of the country unable to provide placements. There have been some positive reflections on T-levels from both institutions and students[169]. Several of the universities involved in hosting T-level placements reflected that through the placements they had been able to develop and support fresh talent, build leadership skills amongst their technical teams, and develop relationships with local colleges. Despite this, recent evidence has shown that T-level students have a lower likelihood of completing a full level 3 qualification by 18 compared to alternative qualifications, and there have been concerns raised over the progression rate from the T-level transition programme to the T-level[170].

Whilst the FE sector provides a wide-range and diverse set of opportunities to learners, supported by a range of providers and links to local employers and industry, funding has been withdrawn from existing alternative qualifications – such as BTECs – leading to wider criticism[171].

164 Royal Society (n.d.). A broad and balanced curriculum. Available at: https://royalsociety.org/news-resources/projects/vision/science-to-18/ (accessed 12 March 2025)

165 Royal Society (2024). Mathematical Futures Programme. Available at: https://royalsociety.org/news-resources/projects/mathematical-futures/ (accessed 12 March 2025)

166 House of Lords (2018). Treating Students Fairly: The Economics of Post-School Education. Available at: https://publications.parliament.uk/pa/ld201719/ldselect/ldeconaf/139/139.pdf (accessed 12 March 2025)

167 UK Parliament (2024). Apprenticeship statistics for England. Available at: https://commonslibrary.parliament.uk/research-briefings/sn06113/ (accessed 12 March 2025)

168 UK government (2023). T-level thematic review: final report. Available at: https://www.gov.uk/government/publications/t-level-thematic-review-final-report/t-level-thematic-review-final-report (accessed 12 March 2025)

169 Positive reflections on T-levels provided by the UK Institute for Technical Skills and Strategy.

170 Education Policy Institute (2024). A quantitative analysis of T level access and progression. Available at: https://epi.org.uk/publications-and-research/a-quantitative-analysis-of-t-level-access-and-progression/ (accessed 12 March 2025)

171 UK Parliament (2023). Education Committee blasts 'disappointing' Govt response to T Levels report. Available at: https://committees.parliament.uk/committee/203/education-committee/news/196242/education-committee-blasts-disappointing-govt-response-to-t-levels-report/ (accessed 12 March 2025)

A key recommendation of the IFS Deaton review on education inequalities noted that the education system must offer high-quality options to young people who pursue vocational options[172].

The quality and availability of careers advice in schools has also been questioned. An independent review found that whilst schools and FE providers understood the importance of careers guidance, and the need to promote the range of academic and technical pathways, not all were achieving this[173]. Indeed, research found that 88% of state school teachers surveyed felt their teacher training did not prepare them to deliver careers information and guidance to students[174].

Limited growth in student numbers and lack of funding with the potential to negatively impact the talent pipeline

There are significant challenges facing the Higher Education sector. The number of core science university courses in the UK has dropped over the past five years: undergraduate degree courses in chemistry have fallen by more than a quarter and biosciences have fallen by 14% since 2019 – 2020[175]. Whilst this decline is in part down to course consolidation and reclassification, analysis suggests there is a decline in undergraduate science students overall (4% and 5% declines for chemistry and biosciences respectively) sparking concerns over the future supply of scientists[176].

PhD students play a vital role in the science ecosystem and over the past decade, growth in domestic and overseas PhD enrolments in the UK has remained broadly flat[177]. Funding is in limited supply. There has been a drop in the number of doctoral students commencing training with the decline in UK-domiciled students being particularly concerning. Between 2018 – 19 to 2022 – 23 the decline in UKRI-funded UK students fell by 29%, compared to 18% for the overall number of doctoral students[178]. The PhD fees for home students are in line with UKRI fee rates (around £4,700 per year), for overseas students – including those from the EU – these can be upwards of £20,000. In contrast, countries such as Germany, Sweden and Norway charge zero fees irrespective of a students' nationality. Funding in the UK for PhD studentships and structured doctoral training, including with industry placements, does exist but is in limited supply. For home PhD students, the introduction of income-contingent loans in 2018 has had limited impact on participation.

Developing UK talent and ensuring a broad range of doctoral training across different disciplines will be critical to supporting the future workforce. Going forward, there is a need for continued monitoring. If numbers continue to decline, this may have a detrimental impact on the talent and skills within the UK research workforce. Wider sector challenges also post a significant threat.

172 Farquharson, C., McNally, S., Tahir, I., (2022). Education Inequalities, IFS Deaton Review of Inequalities. Available at: https://ifs.org.uk/inequality/education-inequalities/ (accessed 12 March 2025)

173 Ofsted (2023). Independent review of careers guidance in schools and further education and skills providers. Available at: https://www.gov.uk/government/publications/independent-review-of-careers-guidance-in-schools-and-further-education-and-skills-providers (accessed 12 March 2025)

174 Holt-White E, Montacute R, Tibbs L (2023). Paving the way. Careers guidance in secondary schools. Available at: https://www.suttontrust.com/wp-content/uploads/2022/03/Paving-the-Way-1.pdf (accessed 12 March 2025)

175 Financial Times (2025). Fall in UK university core science courses stokes fears for industrial strategy. Available at: https://www.ft.com/content/563f9820-d9a6-4e97-99e6-9e6c97919ca3 (accessed 12 March 2025)

176 Financial Times (2025). Fall in UK university core science courses stokes fears for industrial strategy. Available at: https://www.ft.com/content/563f9820-d9a6-4e97-99e6-9e6c97919ca3 (accessed 12 March 2025)

177 HESA (2023). Higher Education Student Statistics: UK, 2021/22. Available at: https://www.hesa.ac.uk/news/19-01-2023/sb265-higher-education-student-statistics (accessed 12 March 2025)

178 Times Higher Education (2024). Is Doctoral Education in the U.K. in Trouble? Available at: https://www.insidehighered.com/news/global/2024/01/12/doctoral-education-uk-trouble (accessed 12 March 2025)

Due to the decreased funding from domestic students and rising costs of research activity, the financial sustainability of the UK university sector is at risk[179]. Despite cross-subsidisation from international student fees, universities remain under significant pressure and at risk of departmental closures with threats to costlier subjects such as chemistry and physics.

Limited stability and career progression at early to mid-career level leading loss of talent from academia

Failure to address the challenges around academic career progression and stability at early and mid-career level is likely to result in a loss of talent from the R&D sector. Due to funding constraints and the lack of a stable funding environment, funders can often only support a small number of individuals despite a wider pool of exceptional researchers. Fellowships are limited and short-term project grants and contracts are prevalent within the academic sector, and this is reflected in the sentiment of early and mid-career researchers, who are significantly less likely to feel secure in their jobs than senior researchers[180]. Mid-career researchers can face this challenge particularly acutely. Considering this, funders such as the Royal Society have developed specialised funding calls targeting talented mid-career scientists to enable them to focus on research for a sustained period[181].

Adequate opportunities for training and development have been identified as a gap for early- and mid-career researchers. Greater entrepreneurship and commercial training for doctoral students has been suggested as a way of supporting the increased and more effective translation of research[182]. In addition, broader transferable skills have been identified as important, both for those pursuing academic or non-academic careers. The Royal Society of Chemistry report on the future workforce highlighted increasing demand for communication, problem-solving and management skills in roles within the chemistry sector[183]. Research hubs provide opportunities to convene researchers from both academia and industry providing opportunities for early-career scientists to train together and collaborate cross-sector[184].

Research assessment narrowing the focus of recruitment in higher education and research institutions

Research assessment continues to heavily influence behaviour across higher education and research institutions. The formula used to allocate mainstream quality-related research (QR) funding – critical for supporting infrastructure, support staff, newly developing and curiosity driven research as well as building research capacity and attracting top talent – incentivises institutions to recruit staff with peer reviewed publications that can be submitted to the REF.

179 Universities UK (2024). Financial sustainability of UK universities: PwC findings. Available at: https://www.universitiesuk.ac.uk/what-we-do/policy-and-research/publications/financial-sustainability-uk-universities (accessed 12 March 2025)

180 Wellcome (2020). What Researchers Think About the Culture They Work In. Available at: https://wellcome.org/reports/what-researchers-think-about-research-culture (accessed 12 March 2025)

181 For example, see the Faraday Discovery Fellowships. Information available here: https://royalsociety.org/grants/faraday-discovery-fellowships/

182 Times Higher Education (2022). We must rethink PhDs to smash barriers and ensure bioscience success. Available at: https://www.timeshighereducation.com/campus/we-must-rethink-phds-smash-barriers-and-ensure-bioscience-success (accessed 12 March 2025)

183 Royal Society of Chemistry (2025). Future workforce and educational pathways. Available at: https://www.rsc.org/globalassets/22-new-perspectives/discovery/future-workforce-and-educational-pathways-interim-report/rsc-future-workforce-ep-report.pdf (accessed 12 March 2025)

184 An example of this is the Sustainable Chemicals and Materials Manufacturing Hub led by the University of Oxford. https://schemahub.ac.uk/hub

It has been suggested that previous recognition frameworks have failed to recognise the contributions of all those involved in research[185], resulting in negative or unintended consequences on the research ecosystem. The incentives created by previous REF exercises resulted in universities increasing investigator numbers at the expense of support, technical and administrative staff or investment in research infrastructure[186]. On the other hand, incentives to recruit talented individuals on open-ended technical, scientific administrative, or research associate contracts, or at the interface of academia and industry in areas such as collaborative R&D, contract research and SME engagement, were weaker in comparison. Whilst the focus on the individual continues, there have been recent changes to the REF. The next REF exercise taking place in 2029 will take a different approach to determining research volume, moving fully away from the assessment of individual researchers.

Different incentives can contribute to vastly differing cultures across academia and industry and can further limit collaboration and porosity. 'People skills' such as communication, teamworking, collaboration and people management are undervalued in academia, yet these individuals are essential for a high performing ecosystem.

Limited mobility between academia, industry and government

Intersectoral mobility supports innovation and is an important tool in increasing the effectiveness of research[187]. The Dowling Review in 2015 found that the UK lags behind countries such as Germany and the USA in encouraging mobility between university and business[188].

Alongside mobility between academia and industry, there are also benefits of promoting mobility for those with scientific training across government and society more broadly. Science-related competencies and training in problem solving and quantitative analysis have been cited as critical to a data- and innovation-driven economy[189]. Having significant numbers of individuals with a science background working within the civil service is likely to also support decision-making around science and R&D policy. Some efforts have been made to bring about changes to research culture, funding and wider system incentives[190], and more recently the National Centre for Universities and Business (NCUB) has done work to build a picture of intersectoral mobility in the UK and how this varies across career stage, discipline, technology sector and industry[191]. Whilst there has been progress, there is a danger that the workforce may remain fairly immobile.

185 Academy of Medical Sciences (n.d.). Team science. Available at: https://acmedsci.ac.uk/policy/policy-projects/team-science (accessed 12 March 2025)

186 UK Government (2023). Research, development and innovation (RDI) organisational landscape: an independent review. Available at: https://www.gov.uk/government/publications/research-development-and-innovation-organisational-landscape-an-independent-review (accessed 12 March 2025)

187 Technopolis (2019). Analysis of intersectoral mobility. Available at: https://www.technopolis-group.com/report/analysis-of-intersectoral-mobility/ (accessed 12 March 2025)

188 UK Government (2015). Independent report – Dowling Review of Business-University Research Collaborations. Available at: https://www.gov.uk/government/publications/business-university-research-collaborations-dowling-review-final-report (accessed 12 March 2025)

189 OECD (2020). Education at a Glance 2020. Available at: https://www.oecd-ilibrary.org/education/education-at-a-glance-2020_69096873-en (accessed 12 March 2025)

190 Royal Society (2017). Changing expectations: where will your career take you? Available at: https://royalsociety.org/blog/2017/06/changing-expectations-where-will-your-career-take-you/ (accessed 13 March 2025)

191 NCUB (2023). Building a data-driven picture of researcher intersectoral mobility in the UK. Available at: https://www.ncub.co.uk/insight/building-a-data-driven-picture-of-researcher-intersectoral-mobility-in-the-uk/ (accessed 12 March 2025)

A report published in 2021 found that the UK civil service had lower proportions of employees with STEM backgrounds, or in STEM occupations, than comparator countries had at the time, including the USA or South Korea[192].

A lack of agile and talent-focussed funding to support international collaboration

The Smith-Reid Review previously identified the absence of funding to support fast-moving opportunities for international collaboration as a major gap in the UK funding landscape[193]. Beyond participating in multilateral schemes such as the Human Frontier Science Program and Marie Skłodowska-Curie Actions, the UK offers relatively little funding for exceptional early and mid- career talent and mobility. In contrast, other countries such as Germany, Switzerland and Singapore offer substantive fellowship schemes to support post-docs to go abroad. Continued lack of funding may limit opportunities for international collaboration and mobility. In addition, to further maximise the opportunities gained from international scientific collaboration, the UK needs a comprehensive international science strategy[194]. This will facilitate the global diffusion of people and ideas, as well as instil confidence in the UK as a predictable environment for investment.

Uncompetitive researcher mobility offer with the highest immigration costs in the world

Analysis commissioned by the Royal Society in 2024 showed that total upfront immigration costs have increased 58% since 2021, with visa costs up to 17 times higher than the average of other leading science nations[195, 196]. The UK has yet to agree substantial reciprocal deals on international mobility and is the only country in western Europe to require EU, EEA and Swiss researchers to apply for visas. If unaddressed the UK will remain uncompetitive when compared to other leading science nations.

Skills gaps and shortages within the R&D workforce

Demand for highly skilled and educated workers is high and particularly pronounced for specific strategic sectors and technologies. Skills gaps and shortages within the R&D workforce can limit the capacity of organisations to identify and acquire useful external knowledge. Skills gaps across the technical workforce have been identified[197], while the (lack of) availability of technical skills impacts the UK's attractiveness for inward investment and the ability of businesses to exploit ideas[198].

192 University of Cambridge (2021). STEM professionals in the UK civil service – an international comparative study, https://www.ciip.group.cam.ac.uk/reports-and-articles/stem-professionals-in-the-uk-civil-service-an-international-comparative-study/ (accessed 12 March 2025)

193 Smith-Reid Review (2019), 'Changes and choices: future frameworks for international collaboration on research and innovation', available from https://www.gov.uk/government/publications/future-frameworks-for-international-collaboration-on-research-and-innovation-independent-advice (accessed 12 March 2025)

194 Royal Society (2023), 'Why the UK needs a comprehensive international science strategy'. Available at https://royalsociety.org/news-resources/publications/2023/uk-international-science-strategy/ (accessed 12 March 2025)

195 Royal Society (2024). Summary of visa costs analysis (2024). Available at: https://royalsociety.org/-/media/policy/publications/2024/summary-of-visa-costs-analysis-2024.pdf (accessed 12 March 2025)

196 Royal Society (2021). Summary of visa costs analysis (2021). Available at: https://royalsociety.org/-/media/policy/publications/2022/visa-costs-comparison-update.pdf (accessed 12 March 2025)

197 Royal Society (2022). Regional absorptive capacity: the skills dimension. Available at: https://royalsociety.org/news-resources/publications/2022/absorptive-capacity/ (accessed 12 March 2025)

198 Department for Business, Innovation and Skills (2014). Insights from international benchmarking of the UK science and innovation system: A report by Tera Allas. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/277090/bis-14-544-insights-from-international-benchmarking-of-the-UK-science-and-innovation-system-bis-analysis-paper-03.pdf (accessed 12 March 2025)

Intermediate technical skills are particularly important for contributing to the adsorptive capacity of organisations and businesses increasing the ability of organisations to understand and apply new ideas and approaches[199]. Currently, demand for skilled workers is partly met by hiring educated workers from overseas[200].

Meeting the demand for skills can be done in two ways: by increasing labour market entrants with tertiary education, and by upskilling the existing workforce[201]. Addressing inequalities in access and improving routes to sub-degree qualifications have been flagged as important ways in which to increase the number of entrants into the labour market who hold tertiary education[202]. In addition, addressing the decline in adult learning and firm-based training will be critical for upskilling the existing workforce.

There are also sector-specific challenges. Within health research there has been a persistent issue with falling numbers of clinical academics. Several factors identified as posing a challenge including inflexible career structures, limited cross sector mobility, inadequate funding for the full costs of health research and a healthcare system that struggles to embed research[203]. This is coupled to broader challenges facing the retention of medical students[204].

Decline in adult learning and firm-based training

Adult learning and upskilling are critical to providing individuals with lifelong opportunity and the ability to adapt to a changing environment and new technologies, and a variety of training programmes are needed to support learners and meet the needs of industry. One of the key drivers of change has been the rapid and widespread digitalisation of work which has led to digital skills becoming essential for many workplaces[205]. As a result of rapid change, many of the skills gaps are widening.

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199 Royal Society (2022). Regional absorptive capacity: the skills dimension. Available at: https://royalsociety.org/news-resources/publications/2022/absorptive-capacity/ (accessed 12 March 2025)

200 Rui Costa, Zhaolu Liu, Sandra McNally, Louise Murphy, Christopher Pissarides, Bertha Rohenkohl, Anna Valero & Guglielmo Ventura (2023). Learning to grow. How to stimulate a skills strategy in an economic strategy. Available at: https://economy2030.resolutionfoundation.org/wp-content/uploads/2023/10/Learning-to-grow-report.pdf (accessed 12 March 2025)

201 Rui C, Liu Z, McNally S, Murphy L, Pissarides C, Rohenkohl B, Valero A and Ventura G (2023). Learning to grow. How to situate a skills strategy in an economic strategy. Available at: https://economy2030.resolutionfoundation.org/wp-content/uploads/2023/10/Learning-to-grow-report.pdf (accessed 12 March 2025)

202 Rui C, Liu Z, McNally S, Murphy L, Pissarides C, Rohenkohl B, Valero A and Ventura G (2023). Learning to grow. How to situate a skills strategy in an economic strategy. Available at: https://economy2030.resolutionfoundation.org/wp-content/uploads/2023/10/Learning-to-grow-report.pdf (accessed 12 March 2025)

203 AMS (2023). Future-proofing UK Health Research: a people-centred, coordinated approach. Available at: https://acmedsci.ac.uk/file-download/23875189 (accessed 12 March 2025)

204 Ferreira T, Collins AM, Feng O, *et al* (2023). Career intentions of medical students in the UK: a national, cross-sectional study. Available at: https://bmjopen.bmj.com/content/13/9/e075598 (accessed 12 March 2025)

205 Carolina Feijao, Isabel Flanagan, Christian Van Stolk, Salil Gunashekar (2021). The global digital skills gap. Available from https://www.rand.org/pubs/research_reports/RRA1533-1.html (accessed 12 March 2025)

Over the last decade, there have been significant cuts to public spending on adult education coupled with decline in the number of adult learners[206]. Whilst the decline is most significant for adults taking qualifications below Level 2, declines in those taking Level 2 or 3 are still significant[207]. Whilst full-time degree participation has increased (due in part to the student loan system), other forms of higher education including part-time undergraduate degrees and sub-degree courses have seen falling numbers. One reason for this is the comparatively lower levels of support that these groups receive in the student loan system[208].

There has also been significant decline in workplace training[209, 210] both within the public and private sectors. Apprenticeships form a critical part of the adult education ecosystem, enabling individuals to gain hands-on work experience and training. Since 2015, there has been a steady decline in the number of apprenticeship starts, primarily driven by the significant decline of those embarking on an Intermediate (Level 2) apprenticeship. Conversely, higher apprenticeships (Level 4 and above) have seen an increase in the same period reflecting a more nuanced picture[211]. The overall drop in apprenticeships has been partially linked to the introduction of the apprenticeship levy in 2017[212]. Whilst many of the issues pre-date the levy, there has been specific criticism that the current apprenticeship levy is too restrictive, and not fit for purpose to meet the training demands of firms[213, 214].

206 Sibieta, Tahir, Waltmann (2022). Adult education: the past, present and future. Available at: https://ifs.org.uk/sites/default/files/output_url_files/BN344-Adult-education-past-present-and-future.pdf (accessed 12 March 2025)

207 Sibieta, Tahir, Waltmann (2022). Adult education: the past, present and future. Available at: https://ifs.org.uk/sites/default/files/output_url_files/BN344-Adult-education-past-present-and-future.pdf (accessed 12 March 2025)

208 Sibieta, Tahir, Waltmann (2022). Adult education: the past, present and future. Available at: https://ifs.org.uk/sites/default/files/output_url_files/BN344-Adult-education-past-present-and-future.pdf (accessed 12 March 2025)

209 Rui C, Liu Z, McNally S, Murphy L, Pissarides C, Rohenkohl B, Valero A and Ventura G (2023). Learning to grow. How to situate a skills strategy in an economic strategy. Available at: https://economy2030.resolutionfoundation.org/wp-content/uploads/2023/10/Learning-to-grow-report.pdf (accessed 12 March 2025)

210 Letter from the Chair, Baroness Taylor of Bolton, to Rt Hon Baroness Smith of Malvern, Minister for Skills on skills for the future: apprenticeships and training, dated 23 October 2024. Available at: https://committees.parliament.uk/work/8388/skills-for-the-future-apprenticeships-and-training/publications/ (accessed 12 March 2025)

211 NFER (2023). Apprenticeships are failing as a vehicle for social mobility. Available at: https://www.nfer.ac.uk/blogs/apprenticeships-are-failing-as-a-vehicle-for-social-mobility/ (accessed 12 March 2025)

212 Sibieta, Tahir, Waltmann (2022). Adult education: the past, present and future. Available at: https://ifs.org.uk/sites/default/files/output_url_files/BN344-Adult-education-past-present-and-future.pdf (accessed 12 March 2025)

213 CBI (2023). Apprenticeships are good, the Apprenticeship Levy needs to work better. Available at: https://www.cbi.org.uk/articles/apprenticeships-are-good-the-apprenticeship-levy-needs-to-work-better/ (accessed 12 March 2025)

214 Letter from the Chair, Baroness Taylor of Bolton, to Rt Hon Baroness Smith of Malvern, Minister for Skills on skills for the future: apprenticeships and training, dated 23 October 2024. Available at: https://committees.parliament.uk/work/8388/skills-for-the-future-apprenticeships-and-training/publications/ (accessed 12 March 2025)

It is increasingly being used to provide employees with higher level skills, rather than an introduction for school-leavers to the world of work, with a significant drop in the number of 16 – 18 year-olds taking up apprentices. There have been calls for an evolution of the Apprenticeship Levy to a more flexible fund that could be used for short courses (which are more accessible to learners), with more targeted training and development to address pressing skills needs[215]. However, risks to the broadening of such a levy have been noted. Subsidising training that would have occurred anyway is costly, as has been the case with past schemes including Train to Gain[216].

There has also been some suggestion that ring-fencing a portion of the Levy for young people, new starters or those with lower levels of qualifications would be an important way to provide greater opportunity to where its most needed[217].

Policy initiatives to tackle declines have been announced, such as the 'Lifelong Loan Entitlement', which will start in 2026. This will provide adults with loans to cover four years of post-18 education. Loans for further education and training can be an unattractive option for the individual, and the Entitlement does not cover those taking a more complex post-18 route such as a longer term of study[218]. In addition, there is a need for greater support for those leaving school with few qualifications. Whilst some interventions such as skills bootcamps may go some way to address this challenge, more effective support and training for this group are still required[219].

215 CBI (2023). Apprenticeships are good, the Apprenticeship Levy needs to work better. Available at: https://www.cbi.org.uk/articles/apprenticeships-are-good-the-apprenticeship-levy-needs-to-work-better/ (accessed 12 March 2025)

216 Tahir I. (2023) Investment in training and skills. Available at: https://ifs.org.uk/publications/investment-training-and-skills (accessed 12 March 2025)

217 Letter from the Chair, Baroness Taylor of Bolton, to Rt Hon Baroness Smith of Malvern, Minister for Skills on skills for the future: apprenticeships and training, dated 23 October 2024. Available at: https://committees.parliament.uk/work/8388/skills-for-the-future-apprenticeships-and-training/publications/ (accessed 12 March 2025)

218 Sibieta, Tahir, Waltmann (2022). Adult education: the past, present and future. Available at: https://ifs.org.uk/sites/default/files/output_url_files/BN344-Adult-education-past-present-and-future.pdf (accessed 12 March 2025)

219 Sibieta, Tahir, Waltmann (2022). Adult education: the past, present and future. Available at: https://ifs.org.uk/sites/default/files/output_url_files/BN344-Adult-education-past-present-and-future.pdf (accessed 12 March 2025)

Lack of diversity within the R&D workforce

A diverse and inclusive science system maximises scientific innovation and creativity and there is strong evidence that diversity drives excellence[220]. A report published by the Science and Technology Committee heard evidence that women, people from certain ethnic backgrounds, disabled people, those from disadvantaged socioeconomic backgrounds and those who identified as being part of the LGBTQ+ community were under-represented in some areas of STEM education, research and employment settings[221].

Short-term contracts and early- and mid-career precarity have been found to disproportionately impact women and those with caring responsibilities[222]. In addition, Black researchers are leaving STEM in greater numbers than other groups at all stages of the career pipeline[223]. This further exacerbates the loss of diverse perspectives, which is known to be important for innovation. Within the technician community, most technicians in the higher education sector are male and the proportion of technicians from minority ethnic groups is much lower compared to academic staff[224].

To ensure a thriving ecosystem which benefits from diverse perspectives and experiences, the barriers facing these communities at different stages of the pipeline need to be addressed.

Case studies

To make progress against government priorities there is a complex array of skills needs. Here we provide three examples illustrating the skills needs for housing, the NHS, and a sustainable food system. These illustrate the need for a holistic approach to skills planning, highlighting the complex drivers of skills shortages at every level, and across different sectors and geographies.

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220 Talia H Swartz, Ann-Gel S Palermo, Sandra K Masur, Judith A Aberg (2019). The Science and Value of Diversity: Closing the Gaps in Our Understanding of Inclusion and Diversity. The Journal of Infectious Diseases, Volume 220, Issue Supplement 2, 15 September 2019, Pages S33–S41, https://doi.org/10.1093/infdis/jiz174 (accessed 12 March 2025)

221 UK Parliament (2023). Diversity and inclusion in STEM – Report Summary. Available at: https://publications.parliament.uk/pa/cm5803/cmselect/cmsctech/95/summary.html (accessed 12 March 2025)

222 Russell Group (2021). Realising Our Potential: Backing Talent and Strengthening UK Research Culture and Environment. Available at: https://russellgroup.ac.uk/policy/publications/realising-our-potential-backing-talent-and-strengthening-uk-research-culture-and-environment/ (accessed 12 March 2025)

223 Royal Society (2021). Ethnicity STEM data for students and academic staff in higher education – analysis for the Royal Society. Available at: https://royalsociety.org/topics-policy/publications/2021/trends-ethnic-minorities-stem/ (accessed 13 March 2025)

224 STEMM-CHANGE project (2019). Equality, Diversity and Inclusion: A Technician Lens. Available at: https://www.stemm-change.co.uk/wp-content/uploads/2019/11/Equality-Diversity-and-Inclusion-A-Technician-Lens-web.pdf (accessed 13 March 2025)

CASE STUDY 1

Skills to ensure affordable and sustainable housing

The UK has a chronic housing shortage, requiring a significant number of new homes to be built each year to keep pace with rising demand[225]. The current government has committed to create more social and affordable housing while ensuring homes are high-quality, well-designed and environmentally sustainable. Consistent with the UK's commitments to reach net zero by 2050, it has also recognised the need to retrofit existing housing stock to improve its energy efficiency and reduce carbon emissions.

Building affordable and environmentally sustainable housing in the UK requires a workforce with a diverse set of skills and qualifications. The application of science, engineering and novel technologies are critical for the green transition in construction. Scientific advances such as in polymers sourced from renewable carbon, low carbon alternatives to cement, and green ways of producing steel and metals are all essential to enabling green construction.

Alongside the development of low carbon and sustainable building materials, meeting climate targets necessitates the people with experience in materials science and new building techniques including chemists, engineers and materials scientists. Structural engineers and architects are fundamental to the design process. Furthermore, AI and digital technologies are being increasingly adopted within the construction industry, and there is likely to be an increase in the need for digital skills around energy modelling and analysis to better support sustainability targets.

Demand for green construction roles is increasing requiring individuals with skills to retrofit buildings such as the installation of heat-pumps and solar panels. In addition, traditional skills in construction, project management and planning will be critical to delivering new homes. Local planning authorities continue to face capacity and skills challenges which have resulted in persistent backlogs in planning applications[226], and large-scale infrastructure projects are at risk from skills shortages, both in terms of engineering and technical skills as well as broader skills in project management and project delivery[227].

225 UK Government (2024). Fact Sheet 1. The need for homes. Available at: https://www.gov.uk/government/publications/new-homes-fact-sheet-1-the-need-for-homes/fact-sheet-1-the-need-for-homes (accessed 13 March 2025)

226 Department for Levelling Up, Housing and Communities (2023). Guidance. Planning skills delivery fund. Available at: https://www.gov.uk/guidance/planning-skills-delivery-fund-year-1-guidance-for-applicants (accessed 13 March 2025)

227 House of Commons (2024). Delivering value from government investment in major projects. Available at: https://committees.parliament.uk/publications/44716/documents/222122/default/ (accessed 13 March 2025)

Persistent challenges around skills in the housing sector include:

Between July – September 2024 vacancies in the construction industry were estimated at 39,000[228], and almost a quarter of businesses (>10 employees) reported shortages in the period between September 2023 – October 2024[229]. Shortages have been identified across every skill level from brick layers and plasterers to civil engineers.

- The Construction Skills Network estimated that 251,500 extra workers will be required to meet UK construction output by 2028, an increase of over 50,000 workers per year[230].
- Despite years of declining construction apprenticeships, there has been an increase over the last couple of years which may help to address some of the demand[231].
- In addition to the challenges around recruitment, the construction sector has been criticised as slow to adapt to digital ways of working. Evidence provided to the House of Lords described a failure of education to meet technological developments within the industry, with a lack of digital training programmes[232].
- The anticipated growth in green industries will lead to increased demand for skills in specialised and sustainable construction techniques[233]. Demand for green and specialised construction roles will increase, such as air source heat pump installation workers and retrofitting of historic buildings. Alongside traditional roles in construction including bricklayers, roofers and carpenters, the Immigration Salary List contains retrofitters as an occupation with a critical shortage[234].

228 Office for National Statistics (2024). VACS02: Vacancies by industry. Available at: https://www.ons.gov.uk/employmentandlabourmarket/peoplenotinwork/unemployment/datasets/vacanciesbyindustryvacs02 (accessed 13 March 2025)

229 Office for National Statistics (2024). Business insights and impact on the UK economy: 24 October 2024. Available at: https://www.ons.gov.uk/businessindustryandtrade/business/businessservices/bulletins/businessinsightsandimpactontheukeconomy/latest (accessed 13 March 2025)

230 Construction Skills Network (2024). CSN Industry Outlook – 2024-2028. Available at: https://www.citb.co.uk/about-citb/construction-industry-research-reports/construction-skills-network-csn (accessed 13 March 2025)

231 Department for Education (2024). Apprenticeships in England by industry characteristics. Academic year 2021/22. Available at: https://explore-education-statistics.service.gov.uk/find-statistics/apprenticeships-in-england-by-industry-characteristics (accessed 13 March 2025)

232 UK Parliament (2022). Build Environment Committee. Meeting housing demand. Available at: https://publications.parliament.uk/pa/ld5802/ldselect/ldbuiltenv/132/13202.htm (accessed 13 March 2025)

233 Department for Education (2024). Skills England: Driving growth and widening opportunities. Available at: https://www.gov.uk/government/publications/skills-england-report-driving-growth-and-widening-opportunities (accessed 13 March 2025)

234 Home Office (2024). Skilled Worker visa: immigration salary list. Available at: https://www.gov.uk/government/publications/skilled-worker-visa-immigration-salary-list/skilled-worker-visa-immigration-salary-list (accessed 13 March 2025)

CASE STUDY 2

Skills to meet the needs of an evolving NHS

The NHS plays a critical role in the health of the UK but faces significant challenges. A commitment to reform the NHS has included priorities around shifting to a more digitally-enabled health service, community care over hospitals, and an increased focus on prevention. In addition, the NHS in England accounts for approximately 40% of all public sector carbon emissions[235]. In line with wider UK commitments on net zero, the NHS has an ambitious aim to meet its targets by 2045.

A range of skills will be required to improve and reform the NHS as well as addressing the longstanding challenges around recruitment and retention. Nurse vacancies consistently account for more than a third of all full-time equivalent vacancies in NHS trusts in England[236]. This is despite measures such as the introduction of additional financial support for student nurses announced back in 2019[237]. Furthermore, the number of fully qualified full-time equivalent GPs has declined since 2015 despite continuing high demand[238]. The challenges around recruitment and retention are a result of multiple factors including pay, working culture and leadership as well as opportunities for flexible working[239].

UK GPs are also among the least satisfied with practising medicine when compared to other high-income countries in terms of work-life balance, workload and time spent with patients[240]. Other parts of the system are also struggling. Whilst clinical research is an essential part of the research and development process to develop and test new medicines and treatments, the falling numbers of clinical academics put the continuation of clinical research at risk[241].

Digital healthcare technologies such as genomics, digital medicine, AI and robotics all offer vast opportunities to improve patient care and diagnostics. Emerging technologies such as low-cost sequencing technology, smartphone apps and biosensors have all been identified as important for healthcare resulting in NHS staff increasingly needing to navigate a data-rich environment[242]. The NHS also provides the opportunity for a large amount of amassed health data. Utilising these datasets to their full potential will require a host of skills around data analysis, alongside knowledge of the legal and regulatory frameworks and potential risks to ensure patient safety.

235 The Health Foundation (2023). Net zero care: what will it take? Available at: https://www.health.org.uk/publications/long-reads/net-zero-care-what-will-it-take (accessed 13 March 2025)

236 Heath Foundation (2023). Retaining NHS nurses: what do trends in staff turnover tell us? Available at: https://www.health.org.uk/news-and-comment/charts-and-infographics/retaining-nhs-nurses-what-do-trends-in-staff-turnover-tell-us (accessed 13 March 2025)

237 DHSC (2019). Nursing students to receive £5,000 payment a year. Available at: https://www.gov.uk/government/news/nursing-students-to-receive-5-000-payment-a-year (accessed 13 March 2025)

238 NHS Digital (2024). General practice workforce. Available at: https://digital.nhs.uk/data-and-information/publications/statistical/general-and-personal-medical-services (accessed 13 March 2025)

239 NHS Pay Review Body (2024). NHS Pay Review Body Thirty Seventh Report 2024. Available at: https://www.gov.uk/government/publications/nhs-pay-review-body-thirty-seventh-report-2024 (accessed 13 March 2025)

240 Jake Beech, Caroline Fraser, Tim Gardner, Luisa Buzelli Skeena Williamson, Hugh Alderwick (2023). Stressed and Overworked What the Commonwealth Fund's 2022 International Health Policy Survey of Primary Care Physicians in 10 Countries means for the UK. Available at: https://www.health.org.uk/publications/reports/stressed-and-overworked (accessed 13 March 2025)

241 AMS (2023). Future-proofing UK Health Research: a people-centred, coordinated approach. Available at: https://acmedsci.ac.uk/file-download/23875189 (accessed 13 March 2025)

242 Health Education England (2019). The Topol Review: Preparing the healthcare workforce to deliver the digital future. Available at: https://topol.hee.nhs.uk/the-topol-review/ (accessed 13 March 2025)

Furthermore, whilst a shift towards prevention can significantly reduce the carbon emissions associated with more intensive treatments[243], the use of digital technologies, AI and cloud computing have significant energy costs. The role of research and innovation in driving the low-carbon transition is likely to be significant, particularly regarding low-carbon care solutions which can be adopted across the workforce[244]. For example, advances in new polymers can help reduce carbon emissions and support the effective management of clinical waste.

Persistent challenges around skills in the NHS include:

- NHS England employs approximately 1.7 million people (1.5 million FTE) and is the country's largest employer with projected demand for staff by 2036 to be in the region of 2.3 million.
- Between July – September 2024 the ONS estimated that there were 149,000 vacancies within the health and social work industry[245]. There were 125,572 vacancies in the NHS between March 2023 – June 2023 representing approximately 9% of the workforce, as well as a significant number of additional roles being filled with temporary staff[246], often at significant additional cost to the NHS.
- There is a significant need to improve digital literacy amongst the health and social care workforce. It is estimated that within 20 years, 90% of all jobs in the NHS will require some form of digital skills[247]. A focus on upskilling the workforce through professional development opportunities, and flexible ongoing training has been identified as critical to delivering the change required. 'Portfolio careers' between those working in the NHS, academia and industry have also been identified as an important factor in delivering change.

243 The Health Foundation (2023). Net zero care: what will it take? Available at: https://www.health.org.uk/publications/long-reads/net-zero-care-what-will-it-take (accessed 13 March 2025)

244 The Health Foundation (2023). Net zero care: what will it take? Available at: https://www.health.org.uk/publications/long-reads/net-zero-care-what-will-it-take (accessed 13 March 2025)

245 ONS (2024). VACS02: Vacancies by industry. Available at: https://www.ons.gov.uk/employmentandlabourmarket/peoplenotinwork/unemployment/datasets/vacanciesbyindustryvacs02 (accessed 13 March 2025)

246 Nuffield Trust (2024). The NHS workforce in numbers. Available at: https://www.nuffieldtrust.org.uk/resource/the-nhs-workforce-in-numbers (accessed 13 March 2025)

247 Health Education England (2019). The Topol Review: Preparing the healthcare workforce to deliver the digital future. Available at: https://topol.hee.nhs.uk/the-topol-review/ (accessed 13 March 2025)

CASE STUDY 3

Skills to ensure a sustainable and secure food system

A sustainable and secure food system is critical to the health of the UK, and global, population. On the one hand food systems must sustain populations, and on the other there are increasing efforts to reduce the environmental impact of food production (including reducing waste and carbon dioxide emissions) and increase the positive impact of food on human health[248]. Whilst food security is critical, it is threatened by climate change, global conflicts, supply chain disruption, events such as the COVID-19 pandemic, and wider geopolitical events[249]. In addition, the food system contributes significantly to climate change and environmental degradation[250]. In the UK, agriculture and land use are responsible for approximately 12% of UK greenhouse gas emissions[251].

Research and innovation are fundamental to building a more sustainable and innovative food production system[252]. The agriculture and land use sectors can support the reduction of carbon emissions through forestry, bioenergy and carbon capture and storage measures. The use of green fertilisers such as green ammonia can reduce carbon emissions, and there have been significant developments in bio-based and degradable polymers for mulch films used to regulate soil temperature and support increased yields.

Progress requires contributions from advancements in fundamental research through to the demonstration and commercialisation of innovative tools and technologies. Alongside scientific advancements, ensuring a sustainable and secure food system requires a wide range of people with experience in farming, agriculture, sustainable chemistry, materials manufacturing, biology and soil science.

Challenges around skills to create a sustainable and secure food system include:

- There are persistent shortages in the food supply chain, with fewer people entering the workforce. In 2021, the UK agri-food supply chain employed 4 million people (approximately 13% of the total number of employees in the UK workforce). Whilst the number of employees had increased in the supply chain from 2000 to 2021 by around 400,000, this was predominantly down to the catering sector whereas agriculture and manufacturing saw significant declines over the same period[253]. In addition, since 2016, there has been a steady reduction in the number of EU migrants working across the food supply chain.

248 National Food Strategy (2021). National Food Strategy: Independent review. Available at: https://www.nationalfoodstrategy.org/the-report/ (accessed 13 March 2025)

249 UK Parliament (2023). Food security. Seventh Report of Session 2022–23. Available at: https://publications.parliament.uk/pa/cm5803/cmselect/cmenvfru/622/report.html (accessed 13 March 2025)

250 National Food Strategy (2021). National Food Strategy: Independent review. Available at: https://www.nationalfoodstrategy.org/the-report/ (accessed 13 March 2025)

251 Green Alliance (2022). Closing the UK's green skills gap. Available at: https://green-alliance.org.uk/wp-content/uploads/2022/01/Closing_the_UKs_green_skills_gap.pdf (accessed 13 March 2025)

252 The Royal Society (2021). Nourishing ten billion sustainably: resilient food production in a time of climate change. Available at: https://royalsociety.org/-/media/policy/projects/climate-change-science-solutions/climate-science-solutions-food.pdf (accessed 13 March 2025)

253 DEFRA (2023). Independent review into labour shortages in the food supply chain. Available at: https://www.gov.uk/government/publications/independent-review-into-labour-shortages-in-the-food-supply-chain (accessed 13 March 2025)

- Businesses are facing challenges in the recruitment of certain skilled roles. Responses to a survey conducted by the independent review of labour shortages in the food supply chain[254] found that over 50% of respondents reported extreme difficulty in filling roles in farm management, and engineering.
- Alongside worker shortages, the transition towards more sustainable agriculture methods demands a transition for skills and knowledge by the workforce. Skills gaps have been identified including around carbon auditing and advice, tree and biomass management, conservation, biodiversity expertise, as well as habitat restoration. Furthermore, whilst automation and new technologies have been suggested as a way of overcoming workforce challenges, they require a highly skilled workforce[255].
- Despite the challenges, the UK has strength in other sectors which may provide a supply of those with relevant skills and experience. For example, some of the processes used to create alternative proteins are similar to those used in the pharmaceutical industry. This provides a potential source of skilled individuals with experience that could be repurposed[256].

254 DEFRA (2023). Independent review into labour shortages in the food supply chain. Available at: https://www.gov.uk/government/publications/independent-review-into-labour-shortages-in-the-food-supply-chain (accessed 13 March 2025)

255 Green Alliance (2022). Closing the UK's green skills gap. Available at: https://green-alliance.org.uk/wp-content/uploads/2022/01/Closing_the_UKs_green_skills_gap.pdf (accessed 13 March 2025)

256 National Food Strategy (2021). National Food Strategy: Independent review. Available at: https://www.nationalfoodstrategy.org/the-report/ (accessed 13 March 2025)

Infrastructure

Infrastructure that supports the science ecosystem

Infrastructure plays a pivotal role in the advancement of science and technology. The development and maintenance of infrastructure is essential for fostering scientific progress and maintaining the nation's competitive edge. However, there has been a general lack of capital investment across the UK, as successive governments have overseen the largest proportional fall in the level of gross fixed capital formation (GFCF) – a measure of how much money a country is investing in long-term assets – of any G7 nation after the pre-financial crisis peak of Quarter 1 (January to March) 2008 (falling by 18.0% from peak-to-trough)[257]. Whilst GFCF has since recovered to similar pre-financial crisis levels, the long term impact of this lack of investment is still evident across the UK economy, particularly in relation to productivity[258].

In recent years there have been efforts to improve the UK's infrastructural capacity, including the roll out of full fibre, electricity decarbonisation, drought resilience, and better infrastructure financing via the National Wealth Fund (formerly the UK Infrastructure Bank)[259]. However, critical barriers remain that hinder productivity and scientific output, such as a lack of laboratory space, data centres and the required energy supply to support them (and other technologies).

These issues are not evenly distributed across the UK, and a question remains on how to get the balance right when it comes to regional investment for the wider economy, as well as in relation to science and technology.

The current government plans to address these issues via a 10-year infrastructure strategy (due to be published in spring 2025 alongside its multi-year spending review)[260]. This will include the plans and long-term approach for transport, energy and housing projects, as well as social infrastructure such as schools and hospitals. The government hopes that their ambition to make significant reforms to planning will help encourage investment, but whether this will be the case in practice remains to be seen.

This section outlines some of the key areas of infrastructure that are required to ensure the science and technology sector can thrive and drive growth in the UK.

257 Office for National Statistics (2017). An international comparison of gross fixed capital formation. Available at: https://www.ons.gov.uk/economy/grossdomesticproductgdp/articles/aninternationalcomparisonofgrossfixedcapitalformation/2017-11-02 (accessed 13 March 2025)

258 Institute for Government (2023). Performance Tracker 2023: Public Services as the UK Approaches a General Election. Available at: https://www.instituteforgovernment.org.uk/publication/performance-tracker-2023 (accessed 13 March 2025)

259 National Infrastructure Commission (2023). Second National Infrastructure Assessment: Baseline Report. Available at: https://nic.org.uk/studies-reports/national-infrastructure-assessment/baseline-report/ (accessed 13 March 2025)

260 HM Treasury (2024). Chief Secretary to the Treasury sets vision for future of Britain's infrastructure. Available at: https://www.gov.uk/government/speeches/chief-secretary-to-the-treasury-sets-vision-for-future-of-britains-infrastructure (accessed 13 March 2025)

Energy infrastructure

The transition to low-carbon energy sources not only supports environmental goals but also ensures the long-term sustainability of scientific operations[261]. There are a number of issues relating to energy infrastructure in the UK, not least deciding on the balance of energy sources to be invested in (hydrogen, wind, solar, nuclear, etc).

One issue that will remain relevant is the need for large scale electricity storage to make the use of renewables, such as wind, more efficient (balancing supply and demand). The Royal Society's report *Large Scale Electricity Storage* highlights the potential for Great Britain's electricity demand to be met by wind and solar by 2050 if supported by greater investment in large-scale storage[262]. However, there are limitations with the day-to-day reliability of renewable energy sources. One solution to supplement renewable energy could be the use of nuclear cogeneration to create stable, low-carbon energy production and baseload capacity[263]. Significant market investments and new market mechanisms are needed to make these kinds of projects more attractive to investors.

As Figure 5 shows, the proportion of electricity consumption represented by renewable energies has increased considerably for electricity-provision purposes (up 30.1% to 45%) between 2013 and 2023[264], though significant month by month variability remains. Although over the same period renewable fuels used in transport and heat have also increased (up 3.8% and 5.7%, respectively), both remain modest when compared with renewable electricity. The effects of weather changes can be seen between 2020 and 2021 and 2015 and 2016.

Planning is also a critical issue here, with several projects in the UK either put on hold or never receiving the green light. A report on the current issues with the planning system in relation to low carbon energy supply emphasises the need for a well-functioning planning system to achieve the UK's decarbonisation goals[265].

Once a project has secured planning permission, there are still further obstacles in linking new energy supplies to the grid, which can result in delays of up to 15 years[266]. In November 2024, Ofgem stated that projects waiting to be connected had reached more than 730 gigawatts, well above the 220 – 225 GW of generation projects the National Electricity System Operator has estimated need to be connected by 2030[267].

261 Thomson, M. (2023). Supporting infrastructure at the heart of research and innovation. Available at: https://www.ukri.org/blog/supporting-infrastructure-at-the-heart-of-research-and-innovation/ (accessed 13 March 2025)

262 Royal Society (2023). Large-scale electricity storage. Available at: https://royalsociety.org/news-resources/projects/low-carbon-energy-programme/large-scale-electricity-storage/ (accessed 13 March 2025)

263 Royal Society (2020) Nuclear cogeneration: civil nuclear energy in a low-carbon future. Available at: https://royalsociety.org/news-resources/projects/low-carbon-energy-programme/nuclear-cogeneration/ (accessed 13 March 2025)

264 Department for Energy Security and Net Zero (2012). Digest of UK Energy Statistics (DUKES): renewable sources of energy. Available at: https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes (accessed 13 March 2025)

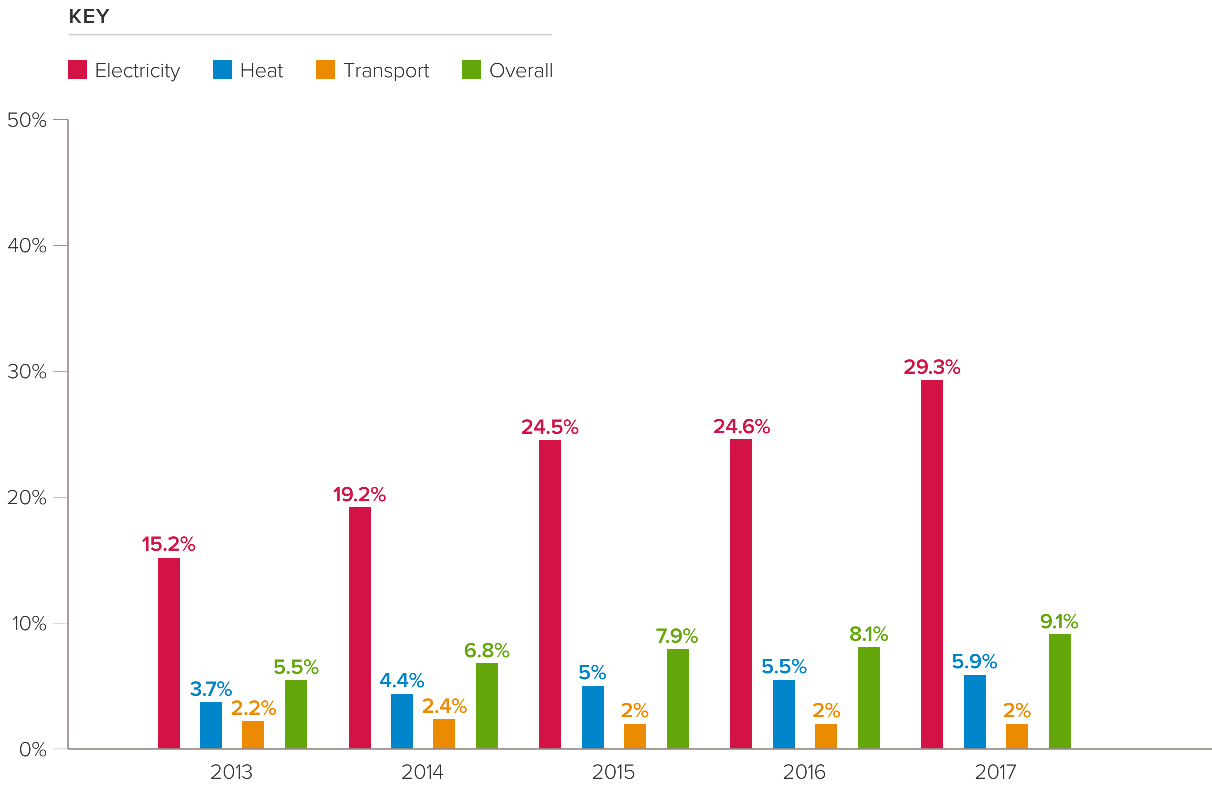
265 CPRE (2024). Electric dreams: how the planning system can help deliver the UK's low-carbon energy. Available at: Planning-Project-Report-2024-Final.pdf (accessed 13 March 2025)

266 Ambrose, J. (2024). Gridlock: why it can take 11 years to connect solar farms to the UK network. Available at: https://www.theguardian.com/business/2024/nov/04/renewable-energy-grid-wait-green-renewal-stellantis-warehouse-solar (accessed 13 March 2025)

267 Office for National Statistics (2024). Business insights and impact on the UK economy: 24 October 2024. Available at: https://www.ons.gov.uk/businessindustryandtrade/business/businessservices/bulletins/businessinsightsandimpactontheukeconomy/latest (accessed 13 March 2025)

FIGURE 5

UK renewable energy as a proportion of total gross final consumption, 2013 – 2023



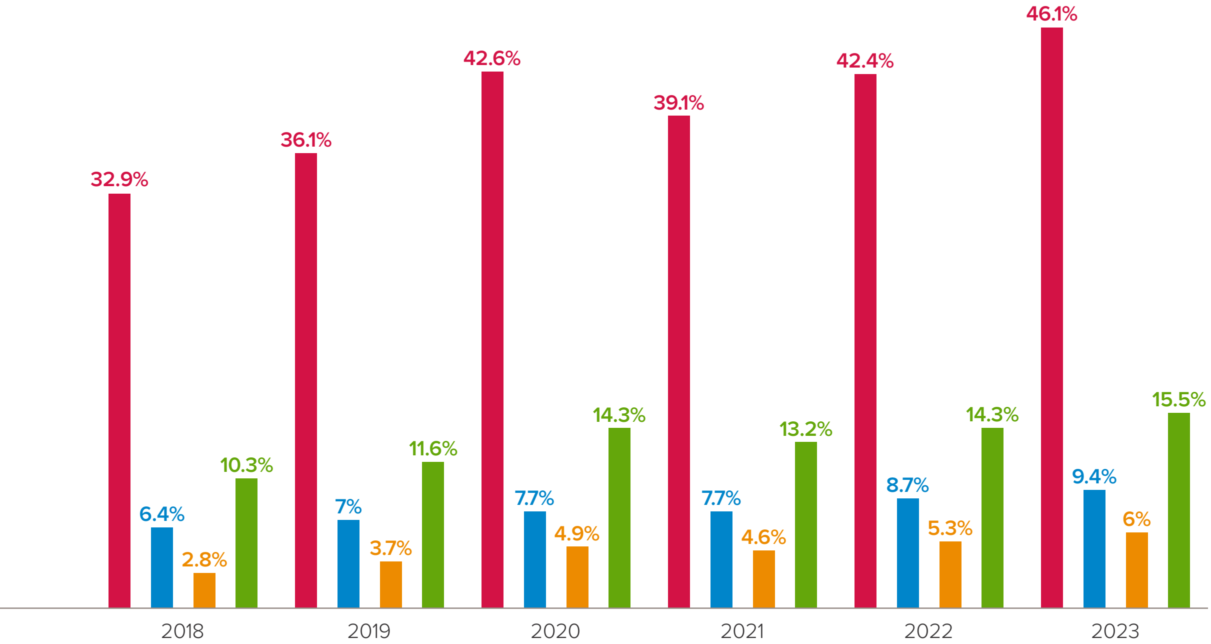
Grid connection is widely considered to be one of the largest barriers to new renewable projects, and therefore to achieving net zero targets[268, 269]. More needs to be done to expand and modernise the grid to ensure that new infrastructure can be connected at pace.

All of this has an impact on energy costs, which in turn has an impact on science in the UK. Research facilities often consume significant amounts of energy[270], and high running costs could threaten the feasibility of research projects. Furthermore, increasing costs will impact on innovation, and the viability of start-ups and SMEs, where there are not significant cash reserves.

268 Matthew Chadwick *et al*. (2024). Hurdling to Net Zero: Overcoming the Obstacles for Renewable Deployment & Investment. Available at: https://www.cornwall-insight.com/files/hurdling-to-net-zero-overcoming-the-obstacles-for-renewable-deployment-and-investment-36658be5.pdf?utm_source=website&utm_medium=website (accessed 13 March 2025)

269 UK Parliament (2024). Grid Connections and Storage Issues Must Be Addressed to Decarbonise the Economy. Available at: https://committees.parliament.uk/committee/62/environmental-audit-committee/news/201721/grid-connections-and-storage-issues-must-be-addressed-to-decarbonise-the-economy-mps-find/ (accessed 13 March 2025)

270 Parker, T. (2011). Cutting science's electricity bill. Nature, 480(7377), pp.315–316. Available at: https://doi.org/10.1038/480315a (accessed 13 March 2025)


32.9%
6.4%
2.8%
10.3%
36.1%
7%
3.7%
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4.9%
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4.6%
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8.7%
5.3%
14.3%
46.1%
9.4%
6%
15.5%
2018
2019
2020
2021
2022
2023

Data centres

Data centres are critical for storing and processing the vast amounts of data generated within the UK economy and play a crucial enabling role for research and innovation in the UK. They provide the computational power necessary for complex simulations, data analysis and the operation of AI systems, which are increasingly integral to scientific research and innovation.

Currently the UK is a world leading market for data centres, with an estimated 400 – 450 data facilities according to a 2020 Tech UK report[271]. Nearly 200 of those are run by commercial operators, who provide third party data centre services, whilst the rest are in house data centres. These are key components of UK economic growth both directly, and indirectly by enabling greater innovation and opportunities for research.

One example of where data centres are a critical contributor within innovation and science is High Performance Computing (HPC). HPC requires bespoke IT hardware and tends to take place in specialist facilities, using parallel processing for complex research projects and large-scale modelling exercises where very large datasets and/ or multiple variables are involved (such as weather forecasting or bioinformatics).

This kind of infrastructure needs to be accessible not just to drive innovation, but also to enable high quality research that is able to be verified and replicated. The Royal Society's report *Science in the age of AI* highlights the limited access to essential infrastructure such as data facilities as one barrier to the conducting and scrutiny of AI experiments. Whilst the report did not review the overall infrastructure landscape, it does demonstrate the various use cases in which AI can be applied, and therefore the importance of having the infrastructure to support this.

271 TechUK (2020). The UK Data Centre Sector Overview. Available at: https://www.techuk.org/resource/uk-data-centre-sector-overview-2020.html

Although data centres require significant amounts of energy, they are also essential to achieving Net Zero, as they can enable the creation of a more digitised and productive economy, whilst also providing the infrastructure to monitor and control emissions[272]. However, the development of data-driven systems that truly contribute to net zero will require better evidence and guidance about their own footprints, including their energy proportionality, as well as new approaches to lower their energy consumption and towards greater integration of renewable energy sources.

However, planning is a key issue when it comes to building new data centres, and this can be particularly difficult for data centres where large spaces, substantial energy and water supply are required. Key issues include Local Planning Authorities (LPAs) handling data centre projects under the town and country planning act 1990, which is the same as how a restaurant or retail development would be considered[273]. This can make it difficult to build centres in optimal locations as there is often local opposition, especially if being built on a greenbelt site, which carry significant weight under current planning laws.

Housing and transport

Housing and transport are critical components for a thriving research and innovation sector. Adequate housing ensures that scientists and researchers can find affordable places to rent or buy near their workplaces, creating greater stability. Efficient transport systems enable connectivity between research institutions, universities and industry hubs. This connectivity is essential for collaboration, knowledge exchange and the timely execution of scientific projects.

Housing and transport are essential elements in encouraging the development of clusters: groups of organisations located in the same place with a shared focus on research and development in a particular field[274]. Some countries have explored the use of 'Talent Housing' or something similar to specifically increase housing capacity to attract and retain talent within clusters[275].

272 Royal Society (2020). Digital Technology and the Planet. Available at: https://royalsociety.org/news-resources/projects/digital-technology-and-the-planet/ (accessed 13 March 2025)

273 Fairweather, E. (2014). Data centres in the UK: challenges and opportunities in development. Available at: https://www.russell-cooke.co.uk/news-and-insights/news/data-centres-in-the-uk-challenges-and-opportunities-in-development (accessed 13 March 2025)

274 Watney C. (2020). Clusters rule everything around me – Works in Progress. Available at: https://worksinprogress.co/issue/clusters-rule-everything-around-me/ (accessed 13 March 2025)

275 Zhang, L., Li, Y., Kung, C.-C., Wu, B. and Zhang, C. (2023). Impact of new talent settlement policy on housing prices: Evidence from 70 large and medium-sized Chinese cities. PLOS ONE, 18(3), p.e0280317. Available at: https://doi.org/10.1371/journal.pone.0280317 (accessed 13 March 2025)

Laboratory space

State-of-the-art labs equipped with advanced instrumentation and technology enable researchers to conduct cutting-edge experiments. However, capacity is currently a key issue with COVID-19 having a longer-term residual impact on capacity levels[276]. The January 2024 progress update on the Government's Review of Science Capability highlighted the underinvestment and underutilisation of public laboratories as a key challenge to the delivery of science advice and knowledge[277]. There is also a question as to whether current public laboratory capacity across the UK is being utilised efficiently.

The Royal Society of Chemistry have highlighted the need for greater investment in laboratory infrastructure and equipment[278], and how current capacity constraints are acting as a barrier to innovation and growth of SMEs[279].

Although UKRI did announce an investment of £103 million in 2023 to expand and upgrade the UK's research infrastructure, only some of this is lab space and is largely set to fund maintenance and upgrading, rather than the building of any new spaces[280].

Despite the clear need for more capacity, building new laboratory space can be difficult. Helen Steiner, CEO of OpenCell (they build biotech labs in shipping containers), has written a comment piece on the difficulties of building new laboratory space, highlighting the lack of interest from private developers due to perceived risk, and whilst large companies such as AstraZeneca have the capital to invest in bespoke infrastructure, growing biotech companies find it more difficult to find the right spaces to conduct their research[281]. The article also highlights the length of time it takes to obtain planning permission for a new laboratory, stating that local government decisions and consultations can slow projects down and sometimes completely derail them.

276 UK Health Security Agency (2023). Audit of Official Laboratories capabilities and accreditation status in the UK 2019 and 2022 results. Available at: https://assets.publishing.service.gov.uk/media/64ba9d072059dc000d5d27f2/Audit-of-official-laboratories-report-2019.pdf (accessed 13 March 2025)

277 Government Office for Science (2024). A review of Government Science Capability: progress update. Available at: https://www.gov.uk/government/publications/government-science-capability-review/a-review-of-government-science-capability-progress-update-9-january-2024 (accessed 13 March 2025)

278 Royal Society of Chemistry (2024). Unlocking Innovation: A Systems Approach to Addressing the Shortage of Chemistry Labs for Startups. Available at: https://www.rsc.org/globalassets/22-new-perspectives/discovery/a-systems-approach-to-addressing-the-shortage-of-chemistry-labs-for-startups/unlocking-innovation-report.pdf (accessed 13 March 2025)

279 Royal Society of Chemistry (2024). Igniting Innovation: The Case for Supporting UK Deep Tech Chemistry. Available at: https://www.rsc.org/globalassets/22-new-perspectives/discovery/igniting-innovation/igniting-innovation-report.pdf (accessed 13 March 2025)

280 UKRI (2023). Investment in World Class Labs to maintain UK infrastructure. Available at: https://www.ukri.org/news/investment-in-world-class-labs-to-maintain-uk-infrastructure/ (accessed 13 March 2025)

281 Steiner, H. (2022). Broken planning system is depriving biotech of quality lab space. Available at: https://www.thetimes.com/uk/article/broken-planning-system-is-depriving-biotech-of-quality-lab-space-gtlxjscpv (accessed 13 March 2025)

Whilst a general lack of capacity in lab spaces poses significant challenges, initiatives like the Laboratory Environmental Assessment Framework (LEAF) offer part of the solution by optimising existing resources and enhancing the sustainability of laboratory operations. It's estimated that laboratories are responsible for around 2% of global plastic waste and use 3 – 10 times more energy per meter squared than a typical office[282]. LEAF addresses these challenges by providing a structured framework that guides lab users through actions to reduce their environmental impact, such as saving plastics, water and energy[283]. Participating laboratories can achieve Bronze, Silver or Gold accreditation based on their sustainability efforts, with the added benefit of estimating their carbon and financial savings using LEAF's inbuilt calculators. Since its inception, LEAF has been adopted by over 85 global institutions, significantly reducing carbon emissions and fostering a culture of sustainable research.

Large-scale research infrastructure

Large-scale research infrastructure (LRI) are research infrastructures large enough to require multilateral funding to construct and operate, of the scale of facilities like the Joint European Torus (JET) or European Organisation for Nuclear Research (CERN). Whether through participation in international projects or hosting facilities domestically, LRI offers opportunities for unique scientific advancements, as well as driving economic development, and global collaboration. At the same time, the long development times and scale of investment require careful planning to ensure investments align with strategic priorities and maximise benefits.

Engagement with LRI – whether through participation in international projects or hosting facilities domestically – presents both opportunities and challenges. Participation provides access to global scientific networks, enhances international standing, and supports collaboration on challenges that transcend national boundaries. These benefits enable the UK to strengthen its scientific capabilities while contributing to the resolution of critical global issues such as climate change, technological innovation and public health.

Domestically hosted infrastructure can support regional economic development, attract international talent and bolster the UK's scientific reputation. It can create high-value jobs, stimulate local supply chains, and act as a magnet global talent, delivering direct benefits to local and regional economies.

282 UCL (n.d.). LEAF – Laboratory Efficiency Assessment Framework. Available at: https://www.ucl.ac.uk/sustainable/take-action/staff-action/leaf-laboratory-efficiency-assessment-framework (accessed 13 March 2025)

283 Sustainability Exchange (n.d.). LEAF – A New Approach to Achieving Laboratory Sustainability. Available at: https://www.sustainabilityexchange.ac.uk/leaf_a_new_approach_to_achieving_laboratory_sus (accessed 13 March 2025)

The significant capital expenditure required to host an infrastructure should not be tensioned against or delivered through the existing UKRI budget, which is already allocated to support the broader research agenda. Instead, hosting large-scale infrastructure requires dedicated investment streams to avoid negatively impacting the wider science system. Hosting also acts as an important capability raising exercise, facilitating the development of the workforce, skills and processes need to construct other high technology infrastructures when needed in the future.

Equally important are the intangible benefits of LRI, such as strengthening the UK's global influence and fostering international collaboration. These aspects, though harder to quantify, play a significant role in the broader impact of research infrastructure.

The last time the UK successfully bid to host a large-scale infrastructure of this magnitude was the Joint European Torus (JET) fusion reactor at Culham, constructed between 1978 and 1983. A 2020 assessment of UK spending on fusion research, including JET, found that the programme delivered significant scientific benefits alongside economic returns estimated at £4 for every £1 invested in the decade 2009 – 2019. JET also contributed thousands of skilled jobs in the Culham area, drove successful spinouts, enhanced the UK's skills capacity, and positioned the country as a key influencer in the emerging regulatory framework for fusion technologies.

Participation in international LRI projects offers clear scientific and economic advantages. It allows access to cutting-edge facilities and fosters collaboration with global talent pools. Collaborative projects such as CERN and EMBL enable the UK to remain at the forefront of high-tech fields like particle physics, bioinformatics, and environmental science. Furthermore, participation enhances the UK's role in addressing global challenges, providing both scientific and diplomatic benefits.

While hosting can foster scientific leadership, alternative approaches – such as distributed or virtual infrastructure – offer some of the same benefits. For example, projects like the Square Kilometre Array Observatory (SKAO) demonstrate how partially hosting world-class facilities can strengthen local research ecosystems and enhance the UK's visibility on the global stage.

Robust governance structures are crucial to ensure projects are well-managed and deliver on their objectives throughout their lifecycle. At present, research infrastructure investment is largely determined by the Department for Science, Innovation and Technology (DSIT) business case process. An independent review led by Lord Willetts concluded that these processes required "an excessive amount of time and effort". Furthermore, the SMART cost-benefit framework underpinning these cases may not fully account for the inherent uncertainty in the impact of research investments, highlighting the need for more flexible and adaptive approaches to appraising research infrastructure.

A strategic framework for LRI decision-making is essential to maximise benefits and minimise risks. Projects should be essential to furthering scientific understanding, with mechanisms needed to cross-compare candidate projects in different areas. LRI also need to align with national and global priorities, addressing critical challenges such as achieving net-zero emissions, building on areas of UK comparative advantage, or advancing critical technology areas. Investments should also demonstrate clear economic benefits, including job creation, local development and return on investment.

Implications for science

The UK's science, research and innovation sectors rely heavily on housing, transport, energy infrastructure, data centres and laboratory space to thrive. However, challenges such as housing shortages, poor transport infrastructure and difficulties in obtaining planning permission for new facilities pose significant barriers to the growth of these sectors. It is evident that targeted investments and streamlined regulatory processes are needed to address these issues.

The common theme across all the infrastructure challenges is the need for better planning and delivery systems, aligned to delivery of scientific and national priorities. The current system can discourage investment and makes it extremely difficult and time consuming for those that do decide to invest in infrastructure. Even where planning is not the main issue, spiralling costs and lack of skilled contractors can impede infrastructure developments[284].

The development and maintenance of quality research infrastructure is critical in ensuring the UK remains at the forefront of scientific research and innovation. Short-term funding cycles hinder the development of this. A long-term investment framework for science generally is essential to provide the stability and predictability necessary to allow this, given by their nature infrastructures are long-term commitments.

Infrastructure commitments also require significant investment from different sources, and the largest infrastructures (whether hosted in the UK or internationally with UK access and participation) will always require international collaboration. An internationally focused science strategy that makes clear UK science priorities is needed to attract and support this global R&D investment.

The section has also stressed the need for alignment between infrastructure planning and national policy goals, particularly in energy, climate science and advanced manufacturing. This reflects the recommendation to coordinate science policy with industrial and infrastructure strategies, ensuring that investment in research facilities supports long-term national priorities.

284 Mellor, J. (2024). Lack of skilled workers risks major infrastructure projects going over budget, PAC warns. Available at: https://feweek.co.uk/lack-of-skilled-workers-risks-major-infrastructure-projects-going-over-budget-pac-warns/ (accessed 13 March 2025)

Incentives

A vision for incentives

Researchers and innovators are motivated by numerous factors including advancing knowledge, contributing to scientific breakthroughs, and having real-world impact. However, the extent to which the aspirations of individuals and those around them can be realised depends on incentives and drivers that exist within the science system which act either as an enabler or a barrier. Researchers are almost always required to apply for funding, are subject to research assessment and evaluation (which typically privilege individual endeavours over 'team science'), and must take part in wider activities to support their own career development and recognition. Some drivers are more prominent in certain parts of the system. In academia there is a greater focus on publishing scientific outputs and contributing to the wider body of knowledge. In science-based industry on the other hand there is a greater focus on improving products and processes, or creating new ones, to meet customer need. Despite the differences however, there is common ground. Individuals and teams working across the system ultimately want to conduct excellent science and make the world a better place by whatever measure.

There is concern in the literature that current incentives operating across the science system may not contribute to these broad goals. Modelling has shown that many of the current incentive structures conflict with the desired values of scientific research[285, 286] and there has been persistent criticism of the ways in which researchers are assessed and recognised, as well as publishing practices and funding mechanisms more broadly.

Developing a science system which incentivises the behaviours associated with conducting excellent and impactful research and innovation is critical to delivering societal impact.

Principles for the future

Here we set out the principles for a future system. These include that the system delivers excellence, delivers research integrity and is inclusive and collaborative.

A system that delivers excellence

The system incentivises individuals and teams to conduct high-quality research that delivers impact. Individuals working across the research and innovation ecosystem are incentivised to conduct world-leading and impactful discovery and applied research. There is a holistic understanding of research excellence to recognise the wide range of research, impacts and people that support the UK research system.

A system that delivers research integrity

The system incentivises researchers to conduct research through trustworthy and rigorous processes. Research is reproducible. There is an open and collaborative research culture. There is a focus on holistic evaluation of researchers and research. Negative results are published.

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285 Higginson AD, Munafò MR. Current Incentives for Scientists Lead to Underpowered Studies with Erroneous Conclusions. PLoS Biol. 2016 Nov 10;14(11) Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC5104444/ (accessed 13 March 2025)

286 Gross K, Bergstrom CT (2024). Rationalizing risk aversion in science: Why incentives to work hard clash with incentives to take risks. PLoS Biol 22(8): e3002750. Available at: https://doi.org/10.1371/journal.pbio.3002750 (accessed 13 March 2025)

A system that is inclusive and collaborative

The system is inclusive. Across the different parts of the science system, there is consideration of research culture and practice, and the system is built around incentivising behaviours which support researchers in their mission to deliver societal impact and minimise the adverse consequences. There are appropriate incentives to ensure recognition of the broad range of ways in which research and development are undertaken.

The system incentivises collaboration. Incentives promote collaboration between higher education institutions, as well as with the wider sector. Individuals are enabled to move and work across sectors and disciplines, supported by the removal of barriers and appropriate incentives.

Behavioural drivers

Whilst many researchers working across academia, industry and the wider research and innovation sector are motivated by a desire to advance knowledge and have societal impact, there are several other drivers that influence researcher behaviour and have an impact on the research conducted. Here, we explore the role that recognition frameworks, funding and institutions have on researcher behaviour.

Recognition and career development

Aside from conducting excellent research, receiving recognition and opportunities for career development are important incentives for researchers. These opportunities can provide researchers with job security and increase the likelihood of future funding or career opportunities, further enabling a researcher's ability to conduct high-impact research.

In academia, publications remain one of the primary ways in which researchers are recognised. Publishing enables researchers to share knowledge and research breakthroughs as well as discuss, debate and build on the existing body of research[287]. Academic researchers are incentivised to publish in journals perceived to be high prestige measured by metrics such as the journal impact factor[288]. Authorship placement also matters, with first- and last- authors often more highly regarded for their contributions.

However, the prioritisation of publication as the primary metric by which a researcher's contribution is assessed has also led to what has been called a perverse incentive to 'publish or perish'. Academics who publish infrequently or who devote more time to teaching than publishing might not be competitive in tenure and promotion processes[289]. In some subject areas there has been a trend towards publishing the minimal publishing unit. As a result, academics submit an increasing number of papers which only incrementally contribute to scientific advancements. Whilst there are many cases where separating research studies into multiple publications is justified, there is increasing concern that some publishable findings are not replicable or have much smaller effects than initially suggested.

287 The Royal Society is currently undertaking a review of the publishing landscape which will be published in 2025.

288 Sharma, M. Sarin, A. Gupta, P. Sachedva, S. and Desai, A.V. (2014). Journal Impact Factor: Its Use, Significance and Limitations, World J Nucl Med 13(2): 146. Available at: https://doi.org/10.4103/1450-1147.139151 (accessed 14 March 2025)

289 Rawat, S., & Meena, S. (2014). Publish or perish: Where are we heading? Journal of research in medical sciences: the official journal of Isfahan University of Medical Sciences. 19(2), 87–89. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC3999612/ (accessed 13 March 2025)

In addition, the focus on publications tends to increase the need for positive, novel findings as opposed to negative or null results[290]. It has been suggested that the prioritisation of publication quantity over quality can lead researchers to feel pressured to cut corners, rush experiences or fabricate data, particularly when promotions, funding and recognition are linked to the number of papers published[291].

Differing incentives may also impact the ability of researchers to move between academia and industry. In industry, researchers often work in multidisciplinary teams and are incentivised by collaborative problem-solving and team success. In academia, the focus often remains on rewarding and recognising the individual through publications, principal investigator grants, and scientific prizes awarded to single individuals or very small groups[292, 293]. Here, team science may be seen as having the potential to devalue individual contributions therefore making it less likely to enhance individual careers. Whilst intersectoral mobility is important for supporting innovation and increasing the effectiveness of research, evidence suggests the UK lags behind other countries in encouraging mobility[294, 295].

The differencing incentives between academia and industry place further barriers in enabling researcher mobility.

Looking ahead there have been calls for a greater focus on replication, open data and the publication of negative results[296]. [297] Initiatives such as registered reports, where journals accept papers based on the experimental design and plans alone and commit to publish whether or not the research produces noteworthy results could change the direction of travel. There have also been increasing calls to move away from quantitative metrics when assessing research and researchers with changes occurring through the evolution of the REF. The San Francisco Declaration on Research Assessment (DORA) sets out the need to eliminate the use of journal-based metrics, such as Journal Impact Factors, in funding, appointment and promotion considerations and assess research on its own merits rather than based on the journal in which the research has been published[298]. However, challenges remain. Qualitative metrics often introduce a degree of subjectivity, and there remains disagreement within the community about which metrics to adopt.

290 Paul Smaldino (2016). Why isn't science better? Look at career incentives. Available at: https://theconversation.com/why-isnt-science-better-look-at-career-incentives-65619 (accessed 13 March 2025)

291 Tran N. (2024). The publish or perish mentality is fuelling research paper retractions – and undermining science. Available at: https://council.science/blog/publish-or-perish-mentality/ (accessed 14 March 2024)

292 Leo Tiokhin and Daniel Lakens (2024). How Science Can Reward Cooperation, Not Just Individual Achievement. Available at https://www.psychologicalscience.org/publications/observer/rewarding-cooperation.html (accessed 13 March 2025)

293 Academy of Medical Sciences (2023). Future-proofing UK health research: a people-centred, coordinated approach. Available at: https://acmedsci.ac.uk/policy/policy-projects/future-proofing-uk-health-research (accessed 13 March 2025)

294 Technopolis (2019). Analysis of intersectoral mobility. Available at: https://www.technopolis-group.com/report/analysis-of-intersectoral-mobility/ (accessed 13 March 2025)

295 UK Government (2015). Independent report – Dowling Review of Business-University Research Collaborations. Available at: https://www.gov.uk/government/publications/business-university-research-collaborations-dowling-review-final-report (accessed 12 March 2025)

296 Paul Smaldino (2016). Why isn't science better? Look at career incentives. Available at: https://theconversation.com/why-isnt-science-better-look-at-career-incentives-65619 (accessed 13 March 2025)

297 Bethany Brookshire (2016). Blame bas incentives for bad science. Available at: https://www.sciencenews.org/blog/scicurious/blame-bad-incentives-bad-science (accessed 13 March 2025)

298 DORA (n.d.). San Franciso Declaration on Research Assessment. Available at: https://sfdora.org/ (accessed 14 March 2025)

By addressing these challenges, the UK can build predictable, well-structured funding and career development pathways. Without these, the UK risks losing its brightest minds to more stable research environments abroad.

Research funding

Scientific research requires significant funding and the continual need to acquire funding is a significant driver of researcher behaviour. In academia, the funding for research comes from two main sources, termed as dual support: institutional funding through QR and project-specific grant funding. Project-related funding is awarded competitively through an established process dependent on expert review, whereas QR funding is allocated based on the quality and volume of research activities undertaken by institutions and is allocated through the REF. In industry, sustained funding for research comes through the commercial success of a company. Products or processes that generate revenue and/or reduce costs are critical to sustaining the organisation. To this end, there is a need to focus on tangible, marketable outcomes that align with the needs of consumers and clients.

The way in which research is evaluated has been called into question. Since the introduction of the REF, as well as its predecessor RAE (Research Assessment Exercise), there has been significant criticism. Whilst it has evolved over time, it has been suggested that there has been a failure to recognise the contributions of all those involved in research[299], resulting in negative or unintended consequences on the research ecosystem. The incentives created by the REF may result in universities increasing investigator numbers at the expense of support, technical and administrative staff or investment in research infrastructure[300].

The REF is acknowledged by the research community as a significant driver of behaviour[301]. Whilst some of these changes are positive such as the increased focus on open research, and public relevance of the research, many are considered negative. Some have criticised the REF for creating perverse incentives around staff recruitment, as well as the inflation of impact and decline of research authenticity and novelty. Overall, it has been suggested that research is less focused on blue sky than predictable outcomes[302].

299 Academy of Medical Sciences (n.d.). Team science. Available at: https://acmedsci.ac.uk/policy/policy-projects/team-science (accessed 12 March 2025)

300 UK Government (2023). Research, development and innovation (RDI) organisational landscape: an independent review. Available at: https://www.gov.uk/government/publications/research-development-and-innovation-organisational-landscape-an-independent-review (accessed 13 March 2025)

301 RAND Europe (2021). Understanding perceptions of the Research Excellence Framework among UK researchers. Available at: https://www.rand.org/pubs/research_reports/RRA1278-1.html (accessed 13 March 2025)

302 RAND Europe (2021). Understanding perceptions of the Research Excellence Framework among UK researchers. Available at: https://www.rand.org/pubs/research_reports/RRA1278-1.html (accessed 13 March 2025)

Some of these criticisms also hold true for project-related grant funding. Scientists may try to avoid risks when applying for grant funding, particularly due to the highly competitive nature of being awarded a grant, submitting proposals which are a 'surer bet'. As a result, the research that is conducted may be less likely to have a transformative impact or lead to significant advances[303].

Funding (or lack of) also creates challenges for the translation and commercialisation of research. Attempting to spin-out a company on the back of research is a high-risk endeavour as many spinouts fail. Demand on academics' time is high with activities around publishing, teaching, supervising and conducting research. Therefore, it there is a high opportunity cost to devoting time to these activities[304].

Institution

Alongside the broader publication environment and research assessment exercises, the institution where a researcher is based also plays a key role in shaping an individuals' behaviour. In terms of career development, institutions will stipulate promotion criteria which will shape researcher behaviour. Whilst these are unique to the institution, there are many common themes often including demonstration of high-quality research outputs, successful grant applications and examples of the individual's research standing and reputation in the research community[305].

Universities are also subject to their own pressures and drivers. Currently, universities are facing a challenging fiscal environment and must attract income from students. League tables are one way in which students determine where they will apply, and these tables rank universities on a range of criteria such as student satisfaction, research activity and graduate prospects. Rankings have a significant influence on institutional strategy, affecting various aspects of university operations including elements such as a focus on research output and impact, student satisfaction including teaching and learning, and graduate employability. Many of these criteria will in turn shape what universities expect of their teaching and research staff further shaping these interactions and driving researcher behaviour.

303 Stephan, P (2012). Perverse incentives. Nature 484, 29–31 (2012). Available at: https://doi.org/10.1038/484029a (accessed 13 March 2025)

304 UCI policy unit (2022). Reforming incentives for research and knowledge exchange to strengthen university spinout performance: options and implications: Insights from an expert roundtable. Available at: https://www.ifm.eng.cam.ac.uk/uploads/UCI/knowledgehub/documents/UCI_Policy_note_Incentives_for_Spinouts_vFinal.pdf (accessed 13 March 2025)

305 For example, please see the promotion criteria of the University of Exeter, https://www.exeter.ac.uk/media/universityofexeter/humanresources/learninganddevelopment/exeteracademic/academicprocess2024onwards/Exeter_Academic_Promotions_Criteria.pdf; University of Essex, https://www.essex.ac.uk/-/media/documents/directories/human-resources/probation-and-promotion-criteria.pdf; and the University of Dundee, https://www.dundee.ac.uk/download/105506/media

Uncertainty in research funding discourages risk-taking and innovation. Career precarity among early-career researchers needs to be addressed to ensure scientists can reach their full potential. It calls for reforms to long-term research grants, ensuring funding mechanisms provide stability for talented researchers to develop ambitious projects.

The degree to which successful cross-sectoral collaboration and career mobility will be significant in shaping the future of UK science. Businesses should be incentivised to invest in workforce training, upskilling, and lifelong learning, learning the approaches of other governments as discussed earlier, which have encouraged sustained investment in research and training.

A key issue in all this is the need for more funding models that are both predictable and flexible. Longer term funding envelopes must be balanced with autonomy for funding bodies to allocate resources efficiently, allowing for year-on-year flexibility within longer-term funding frameworks.

The UK must sustain a diverse research ecosystem, supporting universities, national laboratories, independent research institutes and industry-led R&D. A broad institutional base encourages competition, collaboration and resilience, reducing dependence on a narrow set of funding sources. Research independence must also be preserved – scientists, rather than policymakers, should determine funding priorities based on academic merit and long-term strategic need. A more pluralistic and independent funding system will ensure UK science remains dynamic, innovative, and internationally respected.

Innovation

A vision for UK innovation

From the steam engine to catalysis to AlphaFold, the UK has often been the home of disruptive and economically transformative innovation. Our innovation ecosystem however is at a crossroads. Two decades of chop-change policy approaches and short-term thinking by government have impacted investor confidence and the financial sustainability of the UK research base. Domestic productivity growth, of which science-led innovation is an essential driver, has flatlined for most of this period[306]. Other science nations meanwhile, in Europe, the USA and increasingly China, have been ramping up their investment in the economy of tomorrow.

Society faces many challenges up to 2040 from dealing with climate change and the overexploitation of resources and the biosphere, to addressing the consequences of an ageing population and the inevitability of future pandemics. To meet these challenges, UK government, academia and industry must be working in tandem to create the conditions for a thriving innovation economy that delivers wide-ranging benefits for society. Science is critical to this vision, and there are multiple paths by which it generates economic impact[307]. This includes the application of new knowledge and ideas, the generation of skilled people and jobs, and broader benefits such as improved health and wellbeing outcomes and a transition to net-zero. Science and R&D more generally also provide the underpinning for product and process innovation and technological advancement which in turn boosts productivity. In the long run, that means higher living standards.

The UK remains world-leading in fundamental research but is widely considered to underperform when it comes to translating ideas from the lab to the wider world. This relative weakness is reflected in the UK's poor productivity growth and is attributed to narrow specialisation across a few scientific fields involving few firms (which limits the scope for broad-based adoption and diffusion of technologies and other novel applications across the economy), spatial disparities in R&D investment and intensity outside London and the Greater South East, and historic policy choices that have reduced emphasis on more applied R&D and government intervention at higher TRLs. While the division between 'good at basic' and 'bad at applied' understates the complexity of scientific research and the bidirectional relationship between its fundamental and more applied forms, the general consensus is that more science-led innovation would contribute to solving the productivity problem, and that with other countries increasing their expenditure on R&D, the UK must compete more vigorously for globally mobile talent and investment to enhance its share of the economic benefit.

Skills shortages are another area which significantly impact the potential for innovation, limiting the absorptive capacity of organisations. Even though there is likely to be a heavy reliance on data and digital literacy, many young people are still leaving compulsory education with limited mathematics skills or qualifications. Within the workforce, there have also remained longstanding shortages such as technicians and engineers. Unless the UK builds greater coherence across the education system and aligns with workforce needs, this will continue.

306 The Productivity Institute (2024). What explains the UKs productivity problem? Available at: https://www.productivity.ac.uk/news/what-explains-the-uks-productivity-problem/ (accessed 13 March 2025)

307 Royal Society (2024). Science and the Economy. Available at: https://royalsociety.org/news-resources/publications/2024/science-and-the-economy/ (accessed 11 March 2025)

Economic growth is central to the current UK government's missions[308] with science recognised as a critical enabler. This approach must be sustained up to 2040, whoever governs in Westminster and our devolved nations and regions, through joined-up policymaking and stable R&D investment. Long-term support is needed for fundamental research to fuel the innovations of tomorrow but also for applied R&D that drives the diffusion of productivity enhancing practices between firms and places[309].

Principles for the future

Here we set out a high-level vision for innovation in the year 2040. This vision encompasses four principles: (i) that the system is predictable, (ii) that the system is coherent, (iii) that the system supports a diverse range of R&D activity taking place and (iv) that the system is inclusive.

A system that is predictable

6. **The research and innovation ecosystem is supported by predictable and consistent policymaking.**
   The policy landscape is predictable with consistent signals from government leading to greater investment from the private sector. Government priorities remain stable, and policies are communicated clearly. The ecosystem evolves over time in response to a logical direction of travel. The future state is better than the current.

A system that is coherent

7. **There is coherence and alignment across the research and innovation ecosystem.**
   The movement of people between academia and industry is supported, enabling the sharing and diffusion of knowledge and skills. There is coherence across sectors and best practice is shared. A comprehensive approach is taken to join up science policy with that of education policy and workforce development. Those who work in research science are connected to investors and companies rather than sitting in separate domains.

A system that supports a diverse range of R&D activity

8. **The full potential of regions are realised with local economic growth through research and innovation.**
   Place-based policies have the potential to be particularly effective at enabling regional economic growth; something explored in previous Royal Society work on the factors that underpin the emergence of technology clusters[310]. Excellent research and innovation are carried out at a diverse range of institutions, and there is a greater focus on supporting the diffusion and adoption of new technologies through building regional innovation capacity[311]. A range of public and private actors are supported to carry out innovation.

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308 Labour (2024). Labour Party Manifesto 2024. Available at: https://labour.org.uk/change/ (accessed 13 March 2025)

309 The Productivity Institute (2024) 'What explains the UKs productivity problem?' Available from: https://www.productivity.ac.uk/news/what-explains-the-uks-productivity-problem/

310 Royal Society (2020). Research and Innovation Clusters. Available at: https://royalsociety.org/news-resources/publications/2020/research-and-innovation-clusters/ (accessed 13 March 2025)

311 E. O'Sullivan, R. Jones, G. Anzolin (2024) The role of intermediate Research, Development and Innovation institutes in building regional and sectoral innovation capabilities, Productivity Insights Paper No.034, The Productivity Institute. Available at: https://www.productivity.ac.uk/research/the-role-of-intermediate-research-development-and-innovation-institutes-in-building-regional-and-sectoral-innovation-capabilities/ (accessed 28 March 2025)

9. **Regulation helps, rather than hinders innovation.**
   Regulation is smart, outcome and risk-based, and in proportion to the technological advancement. This supports innovative activity and prevents unnecessary barriers from hampering advancement.

A system that is inclusive of all

10. **The system is inclusive and those working across the research and innovation ecosystem are supported.**
    Those working across the research and development ecosystem have opportunities to continually enhance their skills and qualifications. Individuals with diverse backgrounds and experiences are valued. There is an open culture around innovation, and entrepreneurship and enterprise are valued and encouraged.

11. **The system ensures the UK is an attractive environment for investment.**
    The UK has a thriving environment for research and innovation. The environment attracts international investment and there are strong incentives for national and international businesses to stay in the UK.

12. **The system is globally open to talent.**
    The UK research and innovation ecosystem is globally competitive and supports international mobility through reduced barriers to movement. The UK attracts and retains talent.

Opportunities for the UK innovation ecosystem

This section sets out the opportunities facing the UK innovation ecosystem and how these could help achieve the vision put forward for 2040.

Incentivising private investment

In the UK, the private sector is the largest funder and performer of R&D, making it critical to the research and innovation ecosystem. In 2022 the amount of expenditure on R&D performed by businesses was £49.9 billion[312], representing approximately 75% of R&D conducted in the UK[313]. In addition, whilst Foreign Direct Investment (FDI) into the UK has grown over the past year, there has been a significant decline in investment in R&D activity. Between 2022 and 2023, R&D projects fell by 44%[314]. There are a range of different factors which incentivise businesses to invest in R&D[315]. Here we discuss two incentives: R&D tax credits, and access to finance.

312 Office for National Statistics (2024). Research and development expenditure by the UK government: 2022. Available at: https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgovernmentexpenditureonscienceengineeringandtechnology/2022 (accessed 13 March 2025)

313 Office for National Statistics (2024). Research and development expenditure by the UK government: 2022. Available at: https://www.ons.gov.uk/economy/governmentpublicsectorandtaxes/researchanddevelopmentexpenditure/bulletins/ukgovernmentexpenditureonscienceengineeringandtechnology/2022 (accessed 13 March 2025)

314 EY (2024). Stability and growth. EY attractiveness survey. Available at: https://www.ey.com/content/dam/ey-unified-site/ey-com/en-uk/newsroom/2024/07/ey-uk-attractiveness-survey-07-2024.pdf (accessed 13 March 2025)

315 Labour (2024). Labour's business partnership for growth. Available at: https://labour.org.uk/wp-content/uploads/2024/02/A-Partnership-for-Growth.pdf (accessed 13 March 2025)

R&D tax credits play a role in incentivising business investment in R&D but questions have been raised over their effectiveness

The R&D tax relief scheme was first introduced by the UK government in 2000 to incentivise business investment in innovative R&D projects in science and technology[316]. HMRC has estimated that in the tax year 2021 – 2022 £7.6 billion of R&D tax relief was claimed, corresponding to approximately £44.1 billion of R&D expenditure[317]. Recent estimates suggest that for every £1 of tax foregone, up to £3 of R&D is generated[318]. In 2021 the UK gave the second highest level of tax support for businesses conducting R&D (0.33% of GDP) compared to the other OECD countries[319]. Despite this, in the same year the UK was ranked in ninth place for Business Enterprise Research and Development (BERD)[320]. As a result, the effectiveness of R&D tax credits has been called into question and whether a radical re-thinking of the scheme would better support the growth and retention of UK R&D activity[321].

Whilst R&D tax relief has been credited as having a positive impact, it is important to consider how the benefits can be better realised.

Successive policy changes targeting R&D tax credits have led to a lack of clarity and certainty for businesses[322]. The previous UK government merged two existing schemes bringing together the tax relief targeting SMEs, and that targeting large business. There have also been a series of smaller reforms to R&D tax relief aimed at simplifying the incentives and protecting them from abuse[323]. This is critical as HMRC found that in the year 2020 to 2021 the estimated rate of error and fraud as a percentage of the total R&D relief expenditure was 16.7% (£1.13 billion) of which 92% was through the SME scheme[324].

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316 UK Government (2023). Guidance: Claiming Research and Development (R&D) tax reliefs. Available at: https://www.gov.uk/guidance/corporation-tax-research-and-development-rd-relief (accessed 13 March 2025)

317 UK Government (2023). Research and Development Tax Credits Statistics: September 2023, https://www.gov.uk/government/statistics/corporate-tax-research-and-development-tax-credit/research-and-development-tax-credits-statistics-september-2023#key-points (accessed 13 March 2025)

318 Labour (2024). Labour's business partnership for growth. Available at: https://labour.org.uk/wp-content/uploads/2024/02/A-Partnership-for-Growth.pdf (accessed 13 March 2025)

319 OECD (n.d.). R&D tax expenditure and direct government funding of BERD (2021). Available at: https://data-explorer.oecd.org/vis?df[ds]=dsDisseminateFinalDMZ&df[id]=DSD_RDTAX%40DF_RDTAX&df[ag]=OECD.STI.STP&df[vs]=1.0&pd=2020%2C2020&dq=.A.RDTAX.PT_B1GQ..&to[TIME_PERIOD]=false&ly[rw]=REF_AREA&lc=en&pg=0&vw=br (accessed 13 March 2025)

320 OECD (2022). Main Science and Technology Indicators database. Available at: https://www.oecd.org/content/dam/oecd/en/publications/reports/2023/06/main-science-and-technology-indicators-volume-2022-issue-2_542daf66/1cdcb031-en.pdf#page35 (accessed 13 March 2025)

321 D. Connell (2021). Is the UK's flagship industrial policy a costly failure? Available at: https://www.jbs.cam.ac.uk/2021/industrial-policy-failure/ (accessed 28 March 2025)

322 CASE (2024). Backing Business R&D. Available at: https://www.sciencecampaign.org.uk/analysis-and-publications/detail/backing-business-rd/ (accessed 13 March 2025)

323 Songaila L. (2024). Party Manifestos Point to Stability for R&D Tax Relief. Available at: https://granttree.co.uk/blog/r-d-tax-credits/party-manifestos-point-to-stability-for-rd-tax-relief/ (accessed 13 March 2025)

324 HMRC (2023). Annual Reports and Accounts 2022 to 2023. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1179615/HMRC_annual_report_and_accounts_2022_to_2023.pdf (accessed 13 March 2025)

Given the suite of recent change, there may be less will among government or the sector to overhaul tax credits. In its report on Business Partnership for Growth, the Labour party (then in opposition) stated it would aim to provide stability and maintain the current structure for R&D tax relief[325]. The sector has argued for greater inclusion in terms of qualifying costs, and this has recently been expanded to include expenditure relating to cloud computing, data and pure mathematics[326].

As it stands, R&D tax relief is a relatively untargeted measure. On the one hand this is positive as tax relief provides a mechanism with which to support the vast range of R&D activity which occurs in the UK. No sectors or firms are prioritised over others, and the breadth of activity across the system is maintained. On the other, there may be an argument for being more directive in incentivising R&D activity in areas of comparative UK advantage that can achieve the biggest 'bang for buck'. Similarly, the challenges and opportunities open to SMEs differ to those of larger firms, and the question of whether different forms of regulation and support for SMEs warrants further attention.

Access to finance can provide opportunities for innovative small businesses and scale-ups to flourish

Despite a growing start-up ecosystem, the UK lags behind other countries in supporting those start-ups to scale with access to finance being a major barrier. In 2014, the UK Government established the independently managed British Business Bank (BBB) with the aim to increase the supply of finance available to small businesses[327]. The BBB has several finance options for both businesses and investors as well as providing business guidance and regional support[328].

In response to the UK government's Patient Capital Review, British Patient Capital (BPC) was established, a subsidiary of the BBB. The aim of BPC was to crowd-in private investment towards high-growth start-ups, helping more innovative UK companies scale-up and remain in the UK. An evaluation of BPC suggests that it has made good progress against objectives, increasing the supply of additional capital and enabling funds at scale. 24% of BPC-backed firms were late-stage growth companies, in comparison to 9% of all equity-backed companies. In addition, 25% of BPC-backed firms stated that growth would not have been achieved without the investment, with a further 50% suggesting growth would have taken much longer[329]. There was also a positive impact on innovation activity; 92% of surveyed BPC-backed firms used the investment to fund R&D, and 83% went on to commercialise new products or services.

325 Labour (2024). Labour's business partnership for growth. Available at: https://labour.org.uk/wp-content/uploads/2024/02/A-Partnership-for-Growth.pdf (accessed 13 March 2025)

326 Songaila L. (2024). Party Manifestos Point to Stability for R&D Tax Relief. Available at: https://granttree.co.uk/blog/r-d-tax-credits/party-manifestos-point-to-stability-for-rd-tax-relief/ (accessed 13 March 2025)

327 UK Government (2015). Government support for business, Access to Finance. Available at: https://publications.parliament.uk/pa/cm201415/cmselect/cmbis/770/77006.htm (accessed 13 March 2025)

328 British Business Bank (n.d.). British Business Bank. Available at: https://www.british-business-bank.co.uk/ (accessed 13 March 2025)

329 British Business Bank (2023). British Patient Capital Interim Evaluation Report. Available at: https://www.british-business-bank.co.uk/about/research-and-publications/british-patient-capital-interim-evaluation-report-2022 (accessed 13 March 2025)

Patient capital investments require committing capital long-term and thus forgoing immediate returns for potential long-term gains. As a result, pensions are an important source of patient capital[330]. In the 2023 Autumn statement the Chancellor committed up to £250 million under the Long-term Investment for Technology and Science (LIFTS) initiative to support successful proposals to crowd-in institutional investment, particularly defined contribution (DC) pension funds, into UK innovative science and technology companies[331]. Looking ahead, the focus on unlocking the opportunity provided by pension funds is likely to continue. The Labour government for example has committed to review the pensions landscape to increase investment in UK markets[332].

Despite these changes, challenges in accessing finance remain. Analysis of the 2023 Finance and Investment Decisions Survey found several barriers to accessing finance for SMEs including that the finance was too expensive, that there were too many terms and conditions, and that the speed of decision-making was too slow[333].

Direct public investment

Clear, long-term policy can direct and stimulate investment and activity

A stable and predictable policy environment is critical to supporting long-term planning and investment in R&D activity. For example, businesses require clear signals of intent and direction of travel to provide them with the certainty they need to invest. Over the past decade the lack of stability in science and wider policy has caused damage to the sector. A succession of industrial strategies, some lasting a couple of years or less, have made it challenging for businesses to understand and respond to government investment priorities. Financial support, regulation and public procurement have all been subject to change. This has been coupled with changes to immigration policy and costs, impacting the movement of global talent[334].

Stable funding coupled with a clear and consistent industrial policy is likely to stimulate investment into the R&D sector. Whilst any policy must provide some degree of flexibility in order that it remains fit for purpose, the advantages to providing a stable landscape are significant.

330 The Pensions and Lifetime Savings Association (2018). The Long-Term view, Patient capital and illiquid investment: A guide for pension funds, https://www.plsa.co.uk/Portals/0/Documents/Policy-Documents/2018/7523%20Patient%20Capital%20Guide.pdf (accessed 13 March 2025)

331 UK Government (2023). Press release, '£320 million plan to usher innovation and deliver Mansion House Reforms,'. Available at: https://www.gov.uk/government/news/320-million-plan-to-usher-innovation-and-deliver-mansion-house-reforms (accessed 13 March 2025)

332 Labour (2024). Labour Party Manifesto 2024. Available at: https://labour.org.uk/change/ (accessed 13 March 2025)

333 Bank of England (2024). Identifying barriers to productive investment and external finance: a survey of UK SMEs. Available at: https://www.bankofengland.co.uk/quarterly-bulletin/2024/2024/identifying-barriers-to-productive-investment-and-external-finance-a-survey-of-uk-smes (accessed 31 March 2025)

334 Royal Society (2024). Summary of visa costs analysis (2024). Available at: https://royalsociety.org/-/media/policy/publications/2024/summary-of-visa-costs-analysis-2024.pdf (accessed 12 March 2025)

Public investment has a crucial role to play in high-risk high-reward research

In March 2020, the Budget confirmed the UK government's commitment to an £800 million investment in the creation of a new research funding body, based on the principles of the US Defence Advanced Research Projects Agency (DARPA). DARPA focused on transformative science and technological research programmes and has been described as a pioneer for the mission-orientated approach[335]. For ARIA a critical focus was on conducting research that is high risk, with the potential to produce transformative technological change. In addition, it has been given strategic, scientific and culture autonomy; an impetus to invest in the judgement of talented individuals; and financial flexibility and operational freedom to create an agile and efficient funding body[336].

The budget for ARIA is small in comparison to Innovate UK and therefore, questions around the number and size of missions that it can participate in have been raised. There are also trade-offs to consider around funding high-risk research versus that which is more likely to yield positive outcomes. There are also considerations around the proportion of funding directed at missions or specific areas, versus bottom-up research dictated by the sector. A balanced portfolio is likely to yield the best results.

Skills

The success of the UK research and innovation ecosystem is dependent on its workforce

The availability of skilled people has been highlighted as a major factor for influencing business investment in R&D as organisations must have access to individuals with the right skillsets to carry out research and innovation activity[337]. Having skilled people increases the adsorptive capacity for organisations to undergo innovation, and when thinking of innovation clusters and local growth, individuals with leadership, a skilled workforce, and those who can progress research are highlighted as successful components to building a cluster.

While there has been an increasing focus on people and how better to support the UK workforce[338, 339, 340] there remain significant challenges facing the workforce including around the school curriculum and teaching, a lack of alternatives to standard academic qualification options, reduction in firm-based training, limited mobility between industry and academia along with limited permeability of ideas, and issues around international collaboration and talent with high immigration costs. Together these factors contribute to a skills shortage in the R&D system. Technicians and engineers have been highlighted as areas of shortage.

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335 Leicester and Pakozdi (2022). The potential and challenges of the UK's Advanced Research Invention Agency (ARIA). Available at: https://www.frontier-economics.com/uk/en/news-and-insights/articles/article-i9112-rd-moonshot-the-potential-and-challenges-of-the-uks-advanced-research-and-invention-agency-aria/ (accessed 13 March 2025)

336 UK Government (2021). Advanced Research and Invention Agency (ARIA). Available at: https://www.gov.uk/government/publications/advanced-research-and-invention-agency-aria-statement-of-policy-intent/advanced-research-and-invention-agency-aria-policy-statement (accessed 13 March 2025)

337 Royal Academy of Engineering (2018). Increasing R&D investment: business perspectives. Available at: https://raeng.org.uk/media/xncf2mv2/full-increasing-r-d-investment-business-perspectives.pdf (accessed 13 March 2025)

338 UK Government (2021). Research and development (R&D) people and culture strategy. Available at: https://www.gov.uk/government/publications/research-and-development-rd-people-and-culture-strategy (accessed 13 March 2025)

339 Researcher Development Concordat (n.d.). Welcome to the Concordat to Support the Career Development of Researchers. Available at: https://researcherdevelopmentconcordat.ac.uk/ (accessed 13 March 2025)

340 Technician Commitment (n.d.). About us. Available at: https://www.techniciancommitment.org.uk/ (accessed 13 March 2025)

To support the innovation ecosystem and ensure that there is coherence and alignment across the research and innovation ecosystem, there will need to be a joined-up approach to the skills ecosystem, linking skills to industrial strategy.

Addressing regulatory barriers

SMEs currently face a burdensome regulatory system, often designed with larger companies with great administrative resources in mind. This includes lengthy and complex processes for obtaining funding approvals, navigating intellectual property protections, and complying with tax credit applications like the R&D Tax Relief scheme. Additional challenges arise from sector-specific compliance requirements, such as clinical trial approvals for biotech startups or product safety certifications for tech firms. These requirements often necessitate significant time, expertise and financial resources, which can disproportionately impact smaller businesses with limited staff and budgets. Simplifying these processes would allow SMEs to focus on innovation while maintaining compliance.

Smart Regulation is an adaptive and forward-thinking approach to governance that seeks to achieve policy goals effectively while minimising unnecessary burdens on stakeholders. It emphasises flexibility, proportionality and evidence-based practices, ensuring that regulations remain relevant and efficient in a rapidly changing world.

Central to Smart Regulation is the use of innovative tools and methodologies, including AI. AI plays a crucial but complementary role, offering capabilities such as data analysis, pattern recognition, and predictive modelling. These capabilities allow regulators to identify risks, assess impacts, and monitor compliance more effectively and efficiently. For instance, AI can analyse large datasets to detect potential violations in real time or predict emerging challenges, enabling proactive rather than reactive regulatory measures.

However, Smart Regulation is not solely defined by its reliance on technology. Its foundation lies in stakeholder engagement, transparency, and a focus on outcomes rather than rigid, prescriptive rules. By tailoring regulations to specific risks and fostering collaboration among governments, businesses and civil society, this approach supports innovation while protecting public interests.

Ensuring real world impact

The UK has long been a leader in scientific discovery, but its ability to translate research into economic and societal impact remains a key challenge. To maintain its competitive edge, the UK must remove barriers to innovation and ensure that scientific breakthroughs can be rapidly and effectively commercialised.

This section has explored the structural and regulatory challenges that hinder research translation, highlighting the need for streamlined pathways from discovery to application. At present, bureaucratic complexity and a lack of coordination between universities, industry, and government agencies create inefficiencies that slow the pace of innovation. Addressing these barriers will require a coherent national strategy that fosters greater collaboration across sectors.

Regulation plays a crucial role in shaping the innovation landscape. While oversight is necessary to ensure ethical and responsible research, an overly restrictive regulatory environment can stifle progress and discourage investment. A more agile and enabling regulatory framework is essential to ensuring that UK-based research is translated into products, services and technologies that benefit society and the economy.

Equitable access to innovation opportunities must also be prioritised. Ensuring that regional and demographic disparities do not limit participation in research and commercialisation efforts will strengthen the resilience and inclusivity of the UK's innovation ecosystem.

By embracing a more coordinated, flexible and ambitious approach to innovation, the UK can ensure that its world-leading research is not only recognised globally but also delivers real-world impact, driving economic growth and improving lives across society.

Conclusion

Building a science system fit for 2040

This report has set out the case for a long-term, strategic approach to science and innovation policy in the UK. Drawing on historical experience, international comparisons, and current structural challenges, it highlights the importance of sustained investment, institutional coherence, and clearly defined national priorities. At the heart of the analysis is a recognition that science cannot deliver its full economic and societal potential in an environment shaped by short-termism, fragmented initiatives, and unstable funding.

The UK's science base remains strong, but its capacity to turn knowledge into lasting advantage is hindered by gaps in translational infrastructure, underinvestment in research, and inconsistent policy frameworks. As global competition intensifies and the scale of scientific ambition increases, the need for a more joined-up and resilient system becomes ever more pressing.

The recommendations set out at the beginning of this report – committing to a clear long-term science strategy, strengthening the skills and education ecosystem, and fostering a diverse research and innovation system – are key to ensuring the UK science system is adaptable and resilient, ready for the challenges of 2040. Delivering the recommendations will require commitment and coordination across sectors and government, but the benefits have the potential to be transformative. A more stable, coherent, and forward-looking science system would place the UK in a stronger position to tackle complex challenges, support inclusive growth, and maintain international leadership in research and innovation.

Acknowledgements

The Science 2040 programme is made possible by the generous support of the EP Abraham Cephalosporin Fund.

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The members of the Steering Group involved in this report are listed below. Members acted in an individual and not a representative capacity, and declared any potential conflicts of interest. Members contributed to the project on the basis of their own expertise and good judgement.

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We would like to thank the Officers and members of the Council of the Royal Society for reviewing the final report.

We would also like to thank the members of the Royal Society's Science, Industry and Translation committee and Entrepreneurs-in-residence scheme for the generosity of their advice and guidance in researching and producing parts of this report.

In addition, we would like to thank those too many to list here who responded to the Call for Views sent to the fellowship, or who helped run or participated in the conference or any of the series of thematic workshops that went in to the production of this report. This includes members of the UK Young Academy for their engagement to provide early-career perspectives, and Alister Wilson and Donal O'Herlihy for expertly facilitating a series of futures events.

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We would particularly like to thank members of the two working groups who shaped specific parts of this report.

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Registered Charity No 207043

9 781782 527817

ISBN: 978-1-78252-781-7
Issued: May 2025 DES9206_1