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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

COUNCIL AND TRUSTEES

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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ONS data revisions mean UK R&D spend may be at 2.4% target

Proposed revisions to ONS statistics about R&D in the UK could have consequences for the Government's target to achieve a spend of 2.4% of GDP on R&D, which includes both Government and business investment.

In an article in early October, the Office of National Statistics (ONS) compared its way of collecting statistics on Business Enterprise R&D (BERD) with the data collected by HM Revenue & Customs (HMRC) on R&D credits.

The statistics collected by the two organisations have different coverage and use different methods. While these estimates of R&D would not be expected to fully align, research suggests they should be closer than currently published, says the ONS.

Analysis of the ONS BERD statistics shows that they could be changed to better represent smaller UK businesses, which have accounted for a growing amount of R&D activity in the HMRC statistics over recent years.

Following interim methodological improvements to better represent small businesses, the value of expenditure on R&D performed by UK businesses, according to the ONS BERD survey were £15.0 billion, £15.6 billion, and £16.1 billion higher in 2018, 2019 and 2020 respectively than previously estimated. This information brings the ONS estimates closer to HMRC statistics. The ONS will use these interim improvements in the November 2022 BERD publication, which will include new data for 2021.

An analysis by the magazine *Nature* concludes that "the UK Government has unexpectedly met its research and development (R&D) spending target."

The 2.4% target was based on the average spend in OECD countries when the policy was set in 2017. However, that average spend has now increased to 2.7%. Will the UK Government respond by raising its target further?

https://bit.ly/ONSstatistics
www.nature.com/articles/d41586-022-03275-6

UK fusion reactor

The West Burton power station site in Nottinghamshire has been selected as the home for 'STEP' (Spherical Tokamak for Energy Production), the UK's prototype fusion energy plant which aims to be built by 2040.

Fusion is based on the same physical reactions that power the sun and stars, and is the process by which two light atomic nuclei combine while releasing large amounts of energy. This technology has significant potential to deliver safe, sustainable, low carbon energy for future generations, says the Government.

The STEP programme aims to create thousands of highly skilled jobs during construction and operations, as well as attracting other high-tech industries to the region and furthering the development of science and technology capabilities nationally.

The programme will also commit immediately to the development of apprenticeship schemes in the region, building on the success of the UK Atomic Energy Authority's (UKAEA) Oxfordshire Advanced Skills centre in Culham. Conversations with local providers and employers have already begun, with schemes to start as soon as possible.

The UK Government is providing £220 million for the first phase of STEP, which will see the UK Atomic Energy Authority produce a concept design by 2024.

https://step.ukaea.uk

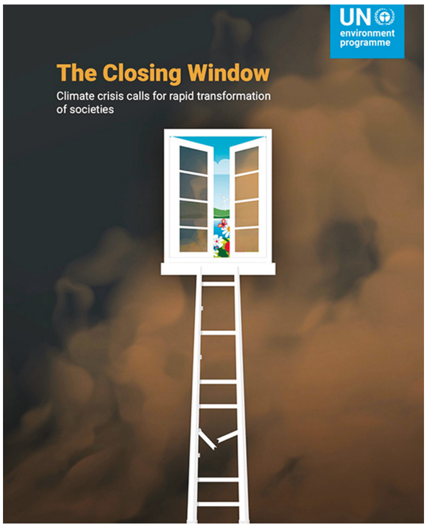
Reports outline climate change challenge

Two reports on climate change from the United Nations Environment Programme (UNEP), published in the lead-up to COP27, demonstrate just how far the world has to go to combat this challenge.

The *Emissions Gap Report 2022* shows that updated national pledges since COP26 in Glasgow make a negligible difference to predicted 2030 emissions and that the world is far from the Paris Agreement goal of limiting global warming to well below 2°C, preferably 1.5°C. Policies currently in place point to a 2.8°C temperature rise by the end of the century. Implementation of the current pledges will only reduce this to a 2.4-2.6°C temperature rise by the end of the century, for conditional and unconditional pledges respectively.

The report finds that only an urgent system-wide transformation can deliver the enormous cuts needed to limit greenhouse gas emissions by 2030: 45% compared with projections based on policies currently in place to get on track to 1.5°C and 30% for 2°C.

The *Adaptation Gap Report 2022* looks at progress in planning, financing and implementing adaptation actions. At least 84% of Parties to the UN Framework Convention on Climate Change (UNFCCC) have established adaptation plans, strategies, laws and policies – up 5% from the previous year. The instruments are getting better at prioritising disadvantaged groups, such as indigenous peoples.



Mind the gap: report says climate policies are inadequate

However, financing to turn these plans and strategies into action is not following, says UNEP. International adaptation finance flows to developing countries are 5–10 times below estimated needs and the gap is widening. Estimated annual adaptation needs are US$160-340 billion by 2030 and $315–565 billion by 2050.

www.unep.org/resources/emissions-gap-report-2022
www.unep.org/resources/adaptation-gap-report-2022

The House of Lords Science and Technology Select Committee has published a report on delivering a UK science and technology strategy: *Science and technology superpower: more than a slogan?*

Delivering a coherent Science and Technology Strategy

Chris Holmes

There is a tremendous economic opportunity for the UK if we invest, streamline, and focus on delivering a clear and coherent national science and technology strategy and I hope this Select Committee report will be an important part of realising that opportunity.

It is also extremely welcome that the Government has increased public funding for the UK Research and Innovation (UKRI) and established the National Science and Technology Council (NSTC) as a cabinet committee as well as creating a new body, the Office for Science and Technology (OST), to prioritise science and technology at the heart of Government.

Both the NSTC and OST have great potential but with their arrival, there is an even greater need to clarify how all the bureaucratic layers will work and be additive rather than, potentially, increasing bureaucracy and blurring accountability. The relationship between these new bodies and key government agencies, particularly UKRI, must be clarified to address this.

The Government is clear about the ambition to be a superpower but in which specific areas and how? While various sectoral strategies in areas such as Artificial Intelligence and life sciences provide more detail and a clearer policy direction, they need to be understood in the context of an overall plan. Initiatives such as the Plan for Growth, the Integrated Review and the Levelling Up White Paper recognise the contribution science and technology can make to a range of policies but have meant that delivery bodies, particularly UKRI, are being pulled in numerous directions with insufficient resources.

The 'science superpower' phrase has been used by Prime Ministers and Chancellors since last year and clearly has wide support with Sir Patrick Vallance also using the phrase this year. Unfortunately, although perhaps inevitably, there is some concern that rather than a coherent strategy it is a political slogan, self-proclaimed rather than objectively substantiated. These doubts will be addressed with greater clarity on the areas laid out in our report and a laser focus on implementation.

Our inquiry makes several detailed recommendations but in essence we need:

- Clear targets and outcome measures
- An understanding of R&D as a long-term endeavour
- A complete commitment to international collaboration and working
- To crowd in private investment
- A laser focus on implementation.

The key findings of the inquiry are summarised in Table 1.

Specific recommendations include:

The Government should set out what, specifically, it wants to achieve in each of the broad areas of science and technology it has identified. There should be a clear implementation plan including measurable targets and key outcomes in priority areas, and an explanation of how they will be delivered. *(Paragraph 18)*

The Government should update Parliament on its progress on developing metrics by the end of 2022. Once metrics are available, an independent body should be empowered to monitor progress towards the Government's science and technology targets and report annually to Parliament and Government. *(Paragraph 20)*

R&D TARGET SPEND

The Government's Autumn Budget Statement has confirmed its commitment to increase the levels of funding for science – specifically £20 billion a year by 2024–25, a fact welcomed by the Commons Science and Technology Select Committee. There is some debate as to whether the UK has already reached its target of 2.4% of GDP on R&D spend (see page 2 of this issue) but the need to set stretching indicative targets and to deliver further increased investment in science and technology is clear.

Lord Chris Holmes of Richmond MBE is an advocate for the potential of technology and the benefits of diversity and inclusion. He is a member of the House of Lords Select Committee on Science and Technology and has previously co-authored House of Lords Select Committee Reports on: Democracy and Digital Technologies (2020), Intergenerational Fairness (2019), Artificial Intelligence (2018), Financial Exclusion (2017), Social Mobility (2016) and Digital Skills (2015). He is co-chair of Parliamentary Groups on Fintech, AI, Blockchain, Assistive Technology and the 4th Industrial Revolution.

The Government is clear about the ambition to be a superpower but in which specific areas and how?

The 'science superpower' phrase clearly has wide support, but there is some concern that it is a political slogan. These doubts will be addressed with greater clarity on the areas laid out in our report and a laser focus on implementation.

Table 1. Key findings of the report.

Reaction	Development
Positive	• 2.4% target, including increasing public investment in R&D • Establishment of Cabinet sub-committee and secretariat (NSTC and OSTS) • Successful network of Chief Scientific Advisers • Suggestion of a more strategic approach with metrics to measure progress
Negative	• Potential exclusion from Horizon, resulting in loss of collaboration and capacity • Cuts to Official Development Assistance (ODA) budget • Frequent policy changes • Proliferation of sector-specific strategies • Additional layers of bureaucracy without clear reporting lines and accountability • Lack of engagement with industry on 2.4% target • Lack of output from Cabinet subcommittee and secretariat • 2.4% target is still behind comparable nations
Queries	• Absence of specific reforms to regulation, procurement, and tax credits • Lack of clarity about relationship between UKRI and Departmental research • Lack of clear long-term commitment to R&D • Unclear how R&D targets fit into overall economic plan • Unclear how Government will overcome risk aversion in R&D investment

In defining an overarching implementation plan, the Government should consolidate existing sector-specific strategies that are working well and monitor progress against them to ensure they provide a clear and consistent message. *(Paragraph 23)*

The Government should make every effort to establish science and technology policy for the long term, building on existing policies and with clear, cross-party support. *(Paragraph 27)*

A cross-Government science strategy must recognise the importance of international collaborations and take steps to rebuild the UK's reputation as a partner. *(Paragraph 42)*

The Government should work with industry and the research base to identify the areas, such as Artificial Intelligence, in which the UK can take a global lead in regulation. *(Paragraph 107)*

Sector-based taskforces should be established, providing a single point of contact with industry, to identify opportunities for regulatory reform, explaining how they will encourage innovation. *(Paragraph 108)*

The Office for Science and Technology must engage intensively with industry to define and implement a science and technology strategy to meet the 2.4% of GDP target. *(Paragraph 124)*

The Government should explain what role the services sector will play in increased research and development spending and outline how the 2.4% target fits with the structure of the UK's economy. *(Paragraph 128)*

The Government must develop clear incentives to encourage late-stage investors and support companies to scale-up. The recommendations of the Life Sciences Scale-up Taskforce should be published. The Government should explore mechanisms to recoup investments from companies that have received public money if they move abroad. *(Paragraph 135)*

The Government should explain what it wants public innovation investment to achieve, which technologies and sectors it wants to support, and which mechanisms it will use to provide funding in each case. *(Paragraph 142)*

We have an exceptional science and technology base in the UK, and we have the opportunity to be at the forefront of the 4th Industrial Revolution.

At the forefront

We have an exceptional science and technology base in the UK and the benefits of science, technology and innovation can extend to the delivery of economic growth, improved public services and strategic international advantage. My own view, and this extends slightly beyond the scope of the inquiry, is that the UK has the opportunity to be at the forefront of the 4th Industrial Revolution. It is clear that in the UK key advantages rest in specific areas such as ethical AI and Distributed Ledger Technologies (DLT). We need to see this developed more in Government, as well as by Government, for Government and, most importantly, for the nation. ☐

DOI: 10.53289/YJGH7652

https://committees.parliament.uk/work/6522/delivering-a-uk-science-and-technology-strategy

CONTEXT

In 2021 and 2022, the UK Government announced in a number of policy documents its aim for the UK to become a 'science superpower'. However, no definition exists for this term. What does becoming a science superpower mean in practice – and how would we get there? What are the opportunities and the challenges?

On 6 July 2022, the Foundation for Science and Technology organised a webinar to discuss these issues. The speakers were: Professor Sarah Main, Executive Director, Campaign for Science and Engineering; Professor Graeme Reid, Chair of Science and Research Policy, University College London; Lisa Brodey, Science Counselor, US Embassy London; and The Lord Rees of Ludlow, House of Lords.

A video recording, presentation slides and speaker audio from the event are available on the FST website at: **www.foundation.org.uk/Events/2022/Scenarios-for-a-Science-Superpower**

What is a 'science superpower'?

Sarah Main and Graeme Reid

SUMMARY

- Successive Governments have called for higher levels of investment in research and innovation
- Recently, this has been accompanied by Government aims of the UK becoming a science superpower
- There is no unambiguous definition of the term 'science superpower'
- Professors Main and Reid have been exploring scenarios for the UK as a science superpower
- This record of the discussion also includes references to more recent events.

Successive Governments have called for increased levels of overall R&D investment in the UK. More recently, this has been set within a wider agenda of making the UK a science superpower. The term 'science superpower' appears to have been interpreted in different ways by different parts of Government. Over the past few months, we explored several scenarios for the science superpower agenda, each one describing a different version of future research and innovation in the UK.

We held roundtable discussions and interviews with stakeholders across the R&D community, including those in sciences and humanities, the business sector, and the various parts of Government with an interest in R&D. We also spoke to funding bodies, think tanks, colleagues in international diplomacy and many more. We are grateful to the British Academy, The School of Advanced Study, and the Wales Innovation Network for their support.

The question we explored was not whether the UK could become a science superpower but, assuming the ambition is realised, what models of a science superpower are available to the UK? What do stakeholders value about each model and what challenges arise under each model? Consequently, what are the choices for policymakers who are pursuing the science superpower agenda?

By harnessing political will and the investment commitments that are already being made, it should be possible to deliver a more innovative R&D-led UK economy and culture.

Levelling up

The term 'science superpower' was used frequently by senior figures in previous Governments. The science superpower agenda is now part of the formal responsibilities of the science minister. Former Prime Minister Boris Johnson linked it to his levelling-up agenda back in 2021. The then Chancellor, Rishi Sunak, connected the science superpower agenda with fiscal incentives such as R&D tax credits in the Spending Review that year. The Chief Scientific Adviser, Sir Patrick Vallance, has written about the global science superpower, associating that ambition with policymaking and strategic advantage. Liz Truss, when Foreign Secretary, linked business investment to the science superpower agenda.

In our discussions, we heard a wide range of reactions to the term 'science superpower'. Some of the most frequent reactions concerned the definition of the term. Many respondents from the research and innovation community said that they did not know what the term meant. Some qualified this, adding thoughts like: 'I don't know what it means, but it sounds exciting, and I want to be part of it.' Others questioned the scope of the

Professor Sarah Main is the Executive Director of the Campaign for Science and Engineering and represents the interests of CaSE members in the media and in high-level discussions with Government Ministers, Parliamentary Committees, Chief Scientific Advisers, and senior civil servants. She engages with industry, charity and academic leaders across the UK science base.

Professor Graeme Reid is Professor of Science and Research Policy at University College London. He chairs the Board of the National Physical Laboratory. He worked in the Business Department, the Cabinet Office, and HM Treasury before moving to UCL in 2014.

The term 'science superpower' has gained wide support. Media coverage indicates large corporates are aligning with the science superpower ambition.

Table 1. Opportunities and challenges of different scenarios

Equal expansion	Business investment	Government priorities
	Opportunities	
Protects domains that may be threatened by further concentration	Case for expanding public spending on R&D	Government priorities reflect consensus (climate, health, defence, etc)
Many stakeholders benefit a little	Pathways from academe to economy	Signals long-term intent that attracts business investment
	Challenges	
Locks weaknesses into the system and prevents radical reform	Policy instruments to attract business investment	Stability of Government priorities over time
Securing more public spending ahead of business investment	Free market influence (e.g. on regional distribution of R&D)	Differences in priorities across devolved nations and regions of the UK

term and asked whether it included humanities, arts, social sciences, engineering and innovation?

There were also some concerns about the term 'superpower', pointing to the colonial overtones, which might have implications in international relations. Some observed that 'superpower' is not an attribute one claims for oneself: rather, it is a recognition that others confer.

However, as a political slogan, the term 'science superpower' has gained wide support. Quotes online and in newspapers show large corporates aligning with the science superpower ambition, often with signals that it may encourage further investment.

Scenarios for research and innovation

R&D investment in the UK currently equates to about 1.8% of GDP (official statistics now show a higher figure following revisions by the ONS) and it has been at that level for decades. The science superpower agenda includes the ambition to rapidly increase that proportion to 2.4% of GDP and beyond.

We developed three scenarios – three versions of that science superpower status. These scenarios are not mutually exclusive. They are designed to highlight choices and stimulate debate about the future of research and innovation in the UK. Each the three scenarios represent a simplified version of how the science superpower agenda might evolve. In reality, some combination of scenarios is likely to emerge.

In the first scenario, the research and innovation system will maintain its current shape. Under this scenario, every part of the research and innovation landscape will expand equally over the coming years, cementing in both the strengths and weaknesses of the existing system.

The second scenario envisages current public spending on research and innovation remaining intact. Business investment in R&D undergoes significant expansion and accounts for the great majority of the expansion of overall levels of R&D

In the third scenario, expansion in R&D is driven largely by the Government's own priorities in areas like public health, climate change, defence and security. Business investment and Government support for the research base remain intact while Government Departments expand their research portfolios substantially.

The equal expansion scenario (Scenario 1), we believe, would not be an attractive option: indeed, at some workshops we described this as 'our null hypothesis'. Yet, in several parts of the country, the scenario was seen as an attractive option: it provided predictability in an uncertain world and offered a degree of protection to parts of the research and innovation community who felt uncomfortable with the prospect of rapidly expanding R&D investment from Government Departments or businesses.

The expansion in business investment in R&D under Scenario 2 has been attractive to finance ministers around the world, including the UK. There are many attractive features of expanded business investment. However, this scenario would mark a shift in the balance of influence with more decisions falling to the marketplace. For example, businesses may well choose to expand their R&D in locations that are at odds with other areas of Government policy. In an extreme example, higher levels of business R&D investment could be concentrated in the South East of England, expanding regional disparities rather than levelling up.

Finally, in Scenario 3, where Government priorities play a much larger part in the research and innovation landscape, a question arises as to which Government? We are seeing progressively greater levels of devolution at national and regional levels in the UK. The Scottish Government takes a different view on nuclear power and a different view on genetically-modified crops from the UK Government. So whose priorities would prevail?

These scenarios present several versions of the future and raise many questions about the balance of influence between Government, researchers themselves and business investors. Opportunities and challenges that arose frequently in our consultations are shown in Table 1. The current balance of influence is the result of a long evolutionary process of policy development. The UK is unfamiliar with a radical perturbation in the level of research investment, shifting the balance of influence over a relatively short time.

There is no obvious consensus on the optimum distribution of influence after R&D investment levels have risen and science superpower status has been secured. Nor is it clear how long it would take for changes in influence to reach a new equilibrium or whether that balance would be stable in the way it has been to date. Hopefully, this work can provide a stimulus for further discussion and debate. □

DOI: 10.53289/DRBP3321

The UK is unfamiliar with a radical perturbation in the level of research investment, shifting the balance of influence over a relatively short time.

Transatlantic ties in science and technology

Lisa Brodey

SUMMARY

- International cooperation in science is vital
- Science grows economies and improves people's lives throughout the world
- Science has been the foundation of our special relationship for centuries
- The US and the UK have agreed to expand science and technology cooperation
- The US is ready and willing to continue our long history of partnership.

The United States government places significant importance on scientific endeavours and it invests more than any other country in research and development. However, technical expertise and scientific knowledge extend far beyond any national borders. Science is a global endeavour. As such, international cooperation in science is as vital as ever, particularly for the betterment of humanity. We collaborate with scientists all over the world on everything from high-energy physics to stem cell research. Science is a way to build bridges with other countries and communities.

International science and technology cooperation is a focus for the Biden administration. Science and technology constitute a core part of our diplomacy, planning and practice. Research and science are core to our decision-making.

There are also opportunities and responsibilities that come with being a science superpower. Science gives the power to address global challenges, such as pandemics and climate change. It grows economies and improves people's lives throughout the world.

Science diplomacy

Science diplomacy is about recognising and facilitating the opportunities while being mindful of the responsibilities that come with being a science superpower. For example, the Office of Science and Technology used its Science Envoy Program to bring together some of our 'science superstars' from the academic community. We support them for a year or more as envoys so they can share their scientific experience overseas and help develop programmes in the countries they engage with, whether that be Egypt, Vietnam, or Azerbaijan, for example. This is an important way of energising our engagement with other countries.

Another way we do this is through the Embassy Science Fellows Program, which takes working scientists from US government agencies, such as the Department of Energy or the Environmental Protection Agency, and loans them to US embassies for around six weeks, bringing their expertise

Lisa Brodey was Environment, Science, Technology, and Health Counselor at the US Embassy in London. She joined the Foreign Service in 1994. Before arriving in London, Lisa earned an MSc in Security Strategy at the National War College. Prior to that, she was director of the Department of State's Office for Science and Technology Cooperation, the office responsible for engaging partner countries on science policy issues that promote economic growth and support the use of science for decision making.

We share a belief in the power of science and technology to improve health, prosperity and security. We have a shared commitment to the importance of investigator-driven research and freedom of inquiry.

with them. For example, an Embassy Science Fellow from the Department of Energy worked on quantum issues in London just before Covid. She made many contacts and connections and laid a foundation for collaboration that is still occurring.

There is a programme for young researchers in emerging economies called Global Innovation through Science and Technology (or GIST). In partnership with the private sector, GIST includes mentoring, pitch competitions and the development of innovation ecosystems: it is a way for the United States to share our wealth of experience in this area. In Tunisia, I met an 18-year-old Tunisian woman who had beaten many more experienced men in a competition we ran.

We also have dozens of bilateral science and technology agreements, like the one with the UK, which articulate a common position on intellectual property rights and the overarching scenarios that guide our research exchanges with other countries. We have had many discussions also with the EU about cooperation with their research programmes and the ways that US-funded scientists can further collaborate.

In some countries where we have science and technology umbrella agreements, the science and research ministries are not the most powerful parts of government. So, having the US or the UK at the table as well raises the priority of their own programmes with their funding ministries. People-to-people and government-to-government relationships are important because our job is to ensure the integrity of the research and a level playing field.

The US and the UK

The UK is our premier partner on science and technology. We share a belief in the power of science and technology to improve health, prosperity and security. We have a shared commitment to the importance of investigator-driven research and freedom of inquiry.

Science has been the foundation of the special relationship between the two countries for centuries. It probably began with Benjamin Franklin's correspondence with the Royal Society on electricity. The UK and US are two 'research powerhouses'. Our scientists have won an impressive 358 Nobel Prizes, we host all of the world's top 10 universities and working together has produced many tangible benefits.

We both value working together across geographical and disciplinary boundaries, with an eye toward unlocking innovative solutions to global challenges. This better positions us to turn that research into new technologies that can change the world and grow our economies. For this reason, the United States and the United Kingdom have agreed to expand our science and technology cooperation.

The new Atlantic Charter came out of the G7 meeting in Cornwall in 2021. In it, the US and the UK resolved to harness and protect our innovative edge in science and technology in order to support our shared security and deliver jobs at home. By this means, we will promote the development and deployment of new standards and technologies which support democratic values and we will continue to invest in research into the biggest challenges facing the world. Building on that resolve, we have further agreed to develop a landmark Science and Technology Partnership.

Science and research also create new jobs, promote levelling up and protect our security. This includes the security of knowing that global challenges are being addressed together. The Atlantic Charter aims to strengthen cooperation in areas such as the resilience and security of critical supply chains, battery technologies and emerging technologies (including Artificial Intelligence), to support economic growth.

Climate science

One of the strongest examples of science undergirding and forging a direction for policy is climate science. Simply put, we would not have been able to achieve so much at COP 26 – the progress on national commitments or the methane pledge, for example – if there had not been overwhelming consensus on the science. Scientists have warned for decades about increased extreme weather events due to global warming. If it were not for the persistence of scientists or activists, we would not have been able to leverage the now settled science and use it to gain momentum in tackling the crisis.

At COP 26, we saw the implementation of science and technology initiatives to tackle those climate challenges. Among these, the US launched Net Zero World to marshal its 17 national laboratories and provide critical technical assistance to key partner countries. In addition, the US and United Arab Emirates led the launch of the Agriculture Innovation Mission for Climate, which has 80 partners and billions of dollars to advance climate-smart agriculture and food systems.

As the UK focuses on its ambitions in science, the US is ready and willing to continue our long history of partnership, not only bilaterally but together as world leaders in the use of science to solve the critical challenges ahead for humans and our planet. ☐

DOI: 10.53289/FAFJ5568

Looking at science as a global endeavour

Martin Rees

SUMMARY

- Universities need to keep track of developments across the world
- Value for money means attracting the top talent and maximising opportunities for big breakthroughs
- Laboratories outside the main university system can provide long-term, full-time research
- Technically-advanced countries like ours can help emerging economies to go straight to greener, sustainable solutions
- A focus on such Grand Challenges can attract the best talent to engineering and science.

We are used to the idea that research is concentrated in universities. This is a system which has prevailed in the US and the UK, but that is not the case everywhere. Although the idea of the research university was invented by Humboldt in Germany, most of that nation's best researchers are now in Max Planck institutes. The kinds of academic career that mix teaching and research are Anglo-Saxon models, although these have now also been widely adopted in the Far East.

Research universities benefit the economy, partly through direct knowledge transfer to industry. However, although work may be channelled towards a few priority challenges, academia should surely collectively cover the whole map of learning. There are two reasons for this. First, to optimise teaching: a very important output of universities is, of course, successful students. The second reason is to maintain a watching brief over the whole world's research, so as to seize on new ideas and run with them. More than 90% of those new ideas come from somewhere else in the world: it is important to be in touch with them.

It is not possible to predict how or if a specific academic research project will pay off or deliver socio-economic benefit. Yet success is more likely in a nurturing environment. Confidence will drive creativity, innovation and risk-taking. That is true in science, but in the arts and in entrepreneurial activity, too. Researchers themselves have the best expertise and the strongest motive for judging which topics hold promise. Their careers depend on making good choices. The difference in payoff between the very best research and the merely good is manyfold.

Value for money

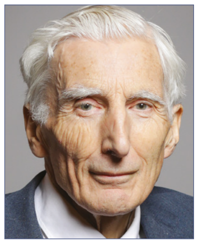
Giving taxpayers enhanced value for money is not about saving a few percent through improving efficiency in the office management sense. It means maximising the chance of big breakthroughs by attracting top talent and supporting them appropriately. These are the people that research universities must attract and nurture.

A perennial tension for funding bodies concerns the support of people versus the support of specific projects. The latter option is administratively tidier and allows the funder to demand quarterly reports of progress, keeping track of steps towards a declared target. The approach is sadly becoming dominant.

Yet history shows that it is often the really free inquiry which leads to the biggest advances. In lively research groups, this is exhilarating. Even in such a privileged environment, though, younger colleagues are ever more preoccupied with grant cuts, proposal writing and job security. Prospects of breakthroughs will plummet if such concerns play unduly on the minds of even the best young researchers.

It is not just in the UK, but also the EU and the US that bodies allocate public funding based on ever more detailed performance indicators to quantify the output. This has the best of intentions, but it can impede best professional practice. One reason why the UK has developed a special strength in biomedical sciences stems from the existence of laboratories that allow the full-time, long-term research that is harder and harder to do in universities. The MRC Laboratory of Molecular Biology, the Crick Institute, the John Innes Centre and the Rothamsted Research Institute, for instance, may allow better environments. There is a downside of course, as they reduce the time talented researchers spend in contact with students.

If 'science superpower' is to be more than just a vacuous phrase, two things are certain. Academia has to attract young people with talent who want to



Lord Martin Rees OM FRS is an astrophysicist and cosmologist, and the UK's Astronomer Royal. He is based at the University of Cambridge where he has been Professor of Astronomy and Director of the Institute of Astronomy. He is a Fellow, and former Master, of Trinity College, Cambridge. In 2005, he was appointed to the House of Lords, and he was President of the Royal Society from 2005 to 2010.

It is often really free inquiry which leads to the biggest advances. But younger colleagues are ever more preoccupied with grant cuts, proposal writing and job security.

HUTTERSTOCK/ WARREN PARKER

The Global South must be economically and technically enabled to leapfrog to clean energy, rather than building coal-fired power stations.

achieve something distinctive in their 30s. We also need to promote percolation between sectors and disciplines: academia is far too rigid in its promotion criteria and facilitating people to enter or leave.

These research institutions must be complemented by organisations (in the public or private sector) which can offer adequate manufacturing capability. Those connections certainly proved their worth in the recent pandemic. It is also imperative that nations like the UK should foster expertise in energy, climate and cyber.

Research is international and it would be good for the UK if there were more top-tier research universities in the rest of Europe, incentivising greater mobility and opportunity. Collectively, that could offer a stronger counter attraction to North America and China as a destination for talent. Sadly, this aspiration has had a serious setback due to Brexit.

Grand Challenges

Looking at the priorities over the near future, the Government has a set of Grand Challenges, one of which is going to be dealing with climate change. For this, real breakthroughs are needed in energy generation, storage and smart grids. There is also a broader and especially compelling motivation for prioritising these efforts in countries like the UK and the US.

Under business-as-usual scenarios, the main rise in annual CO_2 emissions will come in the next 30 years, and from those countries in Southeast Asia and Sub-Saharan Africa which cannot reach acceptable living standards without generating more power than they do today. Their populations are growing and will reach four billion by mid-century. So, flattening the trajectory of their emissions is crucial. The Global South must be economically and technically enabled to leapfrog to clean energy, rather than building coal-fired power stations: much in the way as they have transitioned directly to smartphones, without ever building landlines.

Technically advanced countries like the UK can catalyse a far greater reduction in global emissions by helping the developing world to leapfrog than we can just by achieving net zero ourselves (this country is responsible for less than 2% of global emissions). Similar arguments apply to the challenge of providing the world's food without encroaching on the natural environment, and also of easing the blight of infectious diseases.

Such would be my priorities for long-term Grand Challenges, because of the economic value and because it is hard to think of a more idealistic challenge for attracting young people into engineering than solving these great global problems. □

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The debate

After the presentations, the speakers joined a panel to answer questions from the audience on a variety of topics, including: citations; timescales; targets; Horizon Europe and China.

League tables of citations can be misleading for two reasons. They favour English-speaking countries. In addition, some countries incentivise publishing in certain journals which creates further distortions. Although citations are important, scientific enterprise needs to be underpinned by a common understanding of the ethical ways that research is conducted.

Possible tension

The Government's ambitions are expressed in quite short time horizons and require a radical increase in research investment. This could create a greater tension between quality and quantity than if the growth was taking place over a longer time period. It also means the UK will be in competitions with other countries around the world for extremely talented people and also for investment, particularly from businesses. Both of these groups have a choice of where to locate their efforts.

Unfortunately, the 2.4% target is outdated already. The UK should have an ambition to continue that trajectory upwards, but that must be stable. It will be no good spending five or 10 years reaching an economic goal only to see that decline in the following decade. It needs to be self-sustaining, and indeed growing. It is really important that the investment in R&D is put to good use.

Over the past two decades, despite numerous interventions by governments of different political persuasions, it has been very hard to move that economic metric upwards. It will be a big challenge to move the figure beyond 2.4%. This will require a transformation of the UK economy and culture.

Is it possible for the UK to become a research superpower without full engagement within the EU Horizon Europe? It is very important to maintain links with the UK's nearest collaborators, but that programme is only part of the global research landscape, so the UK will have to re-double its efforts to create partnerships if association with Horizon does not come off.

Forging links

The UK should forge links with talent from China. They are going to be the world leader in many areas and the UK will lose out if it is too guarded about collaboration. We need wider links with major players. Otherwise, we will be moving away from being a superpower rather than towards it.

Being a science superpower means providing better opportunities for business and entrepreneurship and for investment by other countries as well. □

FURTHER INFORMATION

Science superpower – Prime Minister's announcement
www.gov.uk/government/news/pm-sets-out-vision-to-cement-uk-as-a-science-superpower

Science superpower – advice to the Prime Minister
www.gov.uk/government/publications/the-uk-as-a-science-and-technology-superpower

FURTHER INFORMATION

Scenarios for a Science Superpower – podcast with Professor Sarah Main, Executive Director, Campaign for Science and Engineering, and Professor Graeme Reid, Chair of Science and Research Policy, University College London
www.foundation.org.uk/Podcasts/2022/Scenarios-for-a-Science-Superpower-Professor-Graem

Science Superpower – podcast with Matthew Burnett, Head of Science and Technology at Onward.
www.foundation.org.uk/Podcasts/2022/Matthew-Burnett-Science-Superpower

CONTEXT

As the climate continues to change across the globe, there are direct health implications, such as illnesses and fatalities associated with heatwaves. What should the health policy response be to changes in climate, and how do we build this into our plans for a low carbon future?

To explore these issues, the Foundation for Science and Technology held an evening discussion event on 13 July 2022. The speakers were: Professor Sir Chris Whitty, Chief Medical Officer for England; Professor Mike Tipton, Professor of Human and Applied Physiology, University of Portsmouth; and Dr Modi Mwatsama, Head of Climate Interventions, Climate and Health, The Wellcome Trust.

A video recording, presentation slides and speaker audio from the event are available on the FST website at: **www.foundation.org.uk/Events/2022/Health-policy-implications-of-climate-change**

Devising health policies to address climate change

Chris Whitty

Professor Sir Chris Whitty KCB FRCP FFPH FMedSci is Chief Medical Officer (CMO) for England, the UK Government's Chief Medical Adviser and head of the public health profession.

SUMMARY

- Climate change will have negative effects on health everywhere, but there will be gradations in severity
- The healthcare sector needs to get as close to net zero as possible
- Policies that have co-benefits for both mitigation and health should be prioritised
- Countermeasures must be developed against diseases and conditions that will increase with climate change
- Policy goals have costs and the trade-offs need to be acknowledged and minimised.

It is widely accepted that climate change is one of the greatest long-term threats to human health. Climate change effects, once they take hold, are not going to be reversed in the foreseeable future. Even if a resulting health impact itself appears modest, a modest effect for an indefinite period is potentially a major issue.

The negative effects of climate change on health will not be distributed evenly across the globe. There are scientific reasons (biology, atmospheric physics, etc) and reasons of economic and social development. To start with science: there will be an increase in the destructive power of storms and, in essence, this will occur where there are already storms. For people living in the Caribbean, the eastern seaboard of India or parts of Southeast Asia where storms already cause substantial damage, the impact will be large; for other areas it will be smaller.

Other areas will face longer dry periods that could lead to drought and thence to hunger and famine. While that sequence is not inevitable, there is a broad correlation. Again, these effects will be distributed differently in different parts of the world. Such scenarios can be repeated for many different factors and their geographical distribution is not going to be even.

The effects will be exacerbated, though, by the fact that there is also much greater vulnerability to them in some environments than in others. This is largely driven by socio-economic factors. Someone living in the Sahel, for example, will be adversely affected by climate change earlier than someone living in Yorkshire. Vulnerability is however much greater there too, as those with lower incomes have fewer choices and face greater risks. Therefore, the impact on individual lives and on human health will be greater. To be clear, the negative effects on health will be everywhere, but there will be gradations in severity and the least wealthy will suffer the greatest effects wherever they live.

Looking specifically at the UK and Europe, there will be direct effects like increases in heat stress. This was seen in Paris a few years ago, with significant impacts on mortality for people with cardiovascular and other risk factors. There will be increased flooding which can cause mental and physical health effects. These impacts of climate change have direct, negative health impacts.

Then there are also multiple indirect effects. Important vector-borne diseases will change their range. There are a large number of negative consequences from indirect effects on water systems, ranging from people having too little water to wash their hands (which leads to diarrhoeal diseases), through to impacts on the economy, including agriculture – and within that plant and animal health. These will in some regions lead to food insecurity.

Climate change will have major impacts on human socio-economic development. The main predictor of human health, both at country and individual levels, is human socio-economic development and wealth; if climate change slows or reverses economic development, health will suffer. Impacts of climate change will be multigenerational, particularly in Africa and parts of Asia.

Policy responses

There are broadly four areas where a policy response is needed to address the impact of climate change on human health.

To start with, the healthcare industry and profession needs to reduce its own emissions as close to net zero as possible. It is a significant contributor to climate change – not the biggest, but a significant one. Second, we must promote policies that have co-benefits, mitigating carbon emissions and improving health outcomes. Third, it will be necessary to find medical countermeasures against those diseases and conditions which will increase with climate change. There is a responsibility, as part of our efforts at adaptation, to tackle these. Science has a major role to play here.

Finally, and this cannot be stressed too strongly, there must be honesty over trade-offs. There is a tendency to try and wish them away. Yet, that is not being honest and the result will be badly-designed and ineffective policies. People need to be presented with both sides of the argument and make informed decisions. Science has a major role in identifying trade-offs, and then in minimising them.

There are many ways in which the issues surrounding healthcare and climate change can be addressed. The following examples reference the UK, but the same is true in many other countries.

Hospitals and clinics have to be warm (or cool) enough, because they have very vulnerable patients. They also have to be well-ventilated, for reasons of infection and air pollution. This all produces a tension, if at the same time there is an effort to reduce carbon emissions. Opening windows while turning up the heating is not a good solution.

Healthcare produces very large numbers of disposables. This was apparent during Covid, but it is a part of routine service. That means a huge carbon footprint if these are aggregated globally.

The NHS transport fleet is one of the largest in the country, so what it does about its carbon emissions has a big impact on transport more generally.

Then there are specialist areas; for example, some anaesthetic drugs are quite significant greenhouse gases in their own right.

> There are some policies that create tensions. The switch from petrol to diesel may have been good at the margin for carbon but was bad for air pollution.

Policy options

In terms of promoting policies with co-benefits, there are some clear wins. The most obvious is the promotion of 'active travel', that is walking and cycling. In almost every area of health, this will improve people's wellbeing – and of course it is reducing their use of cars. In the 1950s, there were lots of people cycling, so we are just going back to something which was completely normal for our grandparents' generation.

Installing loft insulation would be another policy with co-benefits. It is a very good thing for elderly people as it reduces their bills and keeps them warmer. Additionally, it reduces carbon emissions.

Then, there are more nuanced items, including air pollution. The switch to electric cars will lead to a reduction in tailpipe emissions, which is good for air pollution, there will be a reduction in particulate matters and NOx will be eliminated. In addition, of course, it is good for carbon reduction. It is not a complete answer but it takes us some of the way.

However, there are some policies that create tensions. The switch from petrol to diesel, a deliberate policy decision by the Government, may have been good at the margin for carbon but it was bad for air pollution. The two aims were not brought together under a single policy.

The use of renewable wood for space heating may be good from a carbon point of view but potentially will produce significant increases in particulate matter and air pollution. It is a trade-off, we should be honest about that.

Science and engineering

Science and engineering are hugely powerful in their ability to reduce – although not eliminate – health impacts. As an example, Aedes mosquitoes, which are the vectors of several major diseases including dengue, Zika, chikungunya and Yellow Fever, are steadily moving north through Europe: climate change is contributing to that move. There is a realistic possibility they will become established in the UK. While it will not be possible to eradicate them, we can get rid of the associated diseases (there are already effective vaccines against Yellow Fever).

Engineering solutions can reduce the health impact of, for example, heat stress and flooding. In agriculture, drought- and flood-resistant crops are within the capability of science.

The worst way to make policy is to think that the policy goal does not come at a cost. It is absolutely essential to identify the cost involved and to try and find a way to reduce the tension. We must be honest about trade-offs and then seek as scientists to minimise them. But if we do not tackle climate change, future generations will pay a heavy price in avoidable ill health. ❑

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Understanding human physiology in order to mitigate climate change

Mike Tipton

Mike Tipton MBE PhD MSc FTPS is Professor of Human & Applied Physiology, Extreme Environments Laboratory, University of Portsmouth. He works in the areas of drowning, thermoregulation, extreme environmental physiology and occupational physiology. He is a Trustee of The Physiological Society and a member of the Council of the RNLI, as well as a Consultant to the Medical Director of the RNLI. He is a Fellow of the Royal Society of Medicine and The Physiological Society.

SUMMARY

- Climate change means people will be working and living in more extreme conditions
- In high-income countries, people spend most of their time indoors and have lost their thermal resilience
- An understanding of human physiology enables us to characterise the impact of climate change on human health and productivity, and design environments that help maintain both
- By employing insights into human physiology, it is possible to maintain comfort, health and productivity with less energy consumption and carbon emissions
- A priority is to educate about climate change and thereby promote behavioural change.

There is hardly a day goes by without a headline of some record-breaking bushfire, flood or temperature. It is quite amazing that they do not evoke an urgent response from people: instead they seem largely accepted or ignored. Perhaps climate change is still seen as something that is going to happen in the future, as opposed to more immediate problems like the energy crisis.

Yet these events that are happening now entail substantial costs, about £1.5 billion in damage for each of the 10 extreme events that occurred in 2021. The health costs for malaria, diarrhoea, malnutrition and heat are predicted to reach between £2–4 billion per year by 2030.

Workplace conditions

The Physiological Society is active in this area and has published a report on the impacts of climate change[1]. It covers heat exposure for workforces and other under-researched groups. People are going to be working in more extreme conditions and that results in a decrease in productivity. Looking at the thermoregulatory responses of flood rescuers, the one-in-100-year flood is now happening every two or three years and it is predicted that rescuers working in the warm conditions where they often occur can suffer from heatstroke within about 45 minutes. In areas of deteriorating air quality, there is a 54% increase in deaths associated with heat exposure and high ozone levels.

When the air temperature exceeds 30˚C, there is a nearly 70% increase in the number of drownings. This may be counter-intuitive, but it happens because people choose to leap into cold water to cool off. The water is often still cold enough to induce all the physiological responses that result in drowning.

Food safety, biodiversity, mental health and wellbeing are other areas The Physiological Society has examined in a further report on policy issues[2]. The challenges include: increased average temperatures; extreme weather events; pollution; and disease. Physiologists are looking at ways to improve the situation with the priority on mitigation.

In high-income countries, people have lost their thermal resilience. They spend 90% of their lives living indoors and use about 30% of primary energy sources to keep that indoor environment comfortable in terms of ventilation, heating and air-conditioning.

Why do people in middle- and low-income countries manage much better in warm weather? The answer is twofold. The first point is behavioural adaptation, people know what to do and so change their lifestyle accordingly. Second, they are much more thermally resilient. In countries like the UK, we consume energy and resources to remain 'thermostatic': we do not tolerate or acclimatise to changes in the thermal environment.

Looking at the impact of heat waves, there are a number of health problems associated with being exposed to heat, including increased cardiovascular strain and clot formation. For vulnerable populations such as the elderly, once the air temperature exceeds 26˚C, there is an increase in the number of heat-related deaths. Children are also vulnerable, because they heat up quickly.

The mechanisms of those particular problems are known: a combination of cardiovascular stress, dehydration and, in heat stroke situations, multi-organ failure. The neurophysiology and vascular physiology associated with these problems is known but more information is required about, for example, chronic exposure in specific populations such as children, the elderly, pregnant women, the disabled and people with co-morbidities.

We understand what evokes thermoregulatory responses and how this creates sensations of thermal comfort, heat and cold. We also understand how these relate to the local environment in terms of radiant heat load, air movement, absolute temperature and humidity: it is possible to manipulate these so as to minimise energy costs and still retain comfort. By understanding how the body works ('physiology'), it is possible to reduce a person's dependence on energy-consuming technology, while improving thermal comfort.

As an example of the above, if air velocity across the skin is increased, the ambient temperature thermal comfort threshold can be raised by 3–4˚C. This reduces the reliance on air-conditioning.

Research at Berkeley in the US looked at setpoint temperatures in different US states and cities. Changing the setpoint of the thermostat from 24˚C to 25˚C gives a 7–15% saving in energy use. Just changing the airflow from a 30% minimum airflow to 20% provides a 17% energy saving. These behavioural adaptations can have a significant impact on energy consumption and greenhouse gas emissions. All of these measures are, of course, based on an understanding of human physiology.

The same understanding can be used in the design of the urban environment, determining

In the UK, we consume energy and resources to remain 'thermostatic': we do not tolerate or acclimatise to thermal environment changes.

what will be acceptable to individuals and how to retain levels of thermal comfort. This will involve collaboration between a range of specialists, from botanists, physiologists and medics to architects and town planners – a whole range of different skills coming together to create smarter, cooler, urban spaces.

One of the reasons why there are more deaths during heat waves in urban environments is because they do not cool down overnight. The 'heat island' effect means temperatures stay high so people have deteriorating sleep which has knock-on effects for their health.

The policy priority is to use our understanding of physiology – and the consequences of disturbances to physiology – as the first step in attempting to mitigate and adapt to climate change. As with many other societal challenges, understanding how the body works is critical for optimising the response to climate change.

Multidisciplinary approach

A multidisciplinary approach (and suitable funding models) will be required to address the health challenges of climate change. Policy makers in the UK should be making decisions to keep people in the UK safe – as an immediate policy action – while supporting other countries as well, through research and funding. In terms of media policy, the Physiological Society has called for the Government to name and rank heatwaves. We already do that with storms, but heatwaves kill many more people.

There is plenty of evidence from the LSE, Oxford and various universities around the globe that naming and ranking heatwaves improves focus, improves coordination, is very good for public awareness and understanding and, in addition, promotes behavioural modification. In the short term, an important first step is to get people to appreciate the threat and change the way they behave. ❑

DOI: 10.53289/RPPH7058

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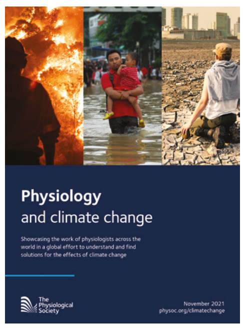

Putting health into the search for climate solutions

Modi Mwatsama

Dr Modi Mwatsama was Head of Interventions for Climate & Health at the Wellcome Trust where she led the Trust's programme of research to support science-based solutions for climate change and health. She is now Head of Capacity and Field Development at the Trust. She joined the Trust in 2018 as Senior Science Lead for Food Systems in the Our Planet, Our Health programme. Prior to Wellcome, Modi was the Director of Policy and Global Health at the UK Health Forum. She is a Registered Nutritionist.

SUMMARY

- The Wellcome Trust's new strategy focusses on some of the world's global health challenges
- By putting health at the heart of climate action, we can progress towards mitigating against and adapting to climate change
- The four goals of the strategy aim to transform this area
- The strategy is global in scope and focussed on health-centred climate mitigation and adaptation
- Emerging economies need help to develop sustainably.

In 2021 September, the Wellcome Trust embarked on a new approach to investing in science in order to solve the world's health challenges. It continues to fund discovery research. The new strategy, meanwhile, is focussing on three of the world's global challenges: infectious diseases, climate and health; and mental health.

The discovery and challenge programmes are underpinned by a major focus on diversity and inclusion, as well as the promotion of positive research cultures in the research that we fund. Over the next 10 years, the Trust is committed to spend £16 billion on this strategy globally.

The world is currently on a trajectory of increasing climate change. Wellcome's mission is to accelerate action and progress towards mitigating climate change by putting health at the heart of climate action and investing in solutions which help protect people from the change that is already baked into the system.

Even if we were to meet the Paris goals, the world will be at least 1.5˚C warmer. So, the Trust will generate evidence to spur action, inform actions to mitigate and adapt, while advocating for coordination and cooperation in order to build a healthy and sustainable future.

The strategy has four goals all of them focussed on transformation. The first is a transformational advance in the availability, access and use of evidence on the direct and indirect effects that climate change will have on people's health in different regions of the world. The Trust will fund research to better understand the mechanisms by which events like increasing floods, fires and droughts will adversely affect people's health. There is a need to quantify those impacts in terms of both health and economic costs.

The second goal is to support a transformational advance in the generation and use of evidence that can identify the effective mitigation actions needed to help meet – or even exceed – the Paris goals, while at the same time promoting health co-benefits.

The third goal is a transformational advance again, this time in the generation and use of evidence to identify effective adaptation solutions to help protect people, vulnerable groups and communities from the adverse effects of health.

The fourth goal is concerned with catalysing a global community of policymakers, the public and communities who are able to understand and use the evidence generated in order to promote health. It will equip researchers from different disciplines to collaborate through activities such as training and fellowships as well as through improved methods and data platforms.

Heat-related issues

We launched a call to evaluate interventions which help protect people from the excess heat exposure in low- and-middle income countries, particularly in Africa, Asia and Latin America. Because it was focussed on communities who were most at risk and affected by climate change, we required the principal investigators to be based in the countries where the research was taking place. They also had to be nationals of those countries and collaborate with local policymakers in the study in order to be better placed to influence those policymakers. We know that policymakers are more inclined to listen to the evidence when it is coming from their own experts and they are engaged in shaping the research priorities. That is a model we are planning to invest in more in future.

We know that policymakers are more inclined to listen to the evidence when it is coming from their own experts and they are engaged in shaping the research priorities.

This particular call recognises that the capacity to undertake this sort of research is less established in developing countries. We are therefore encouraging proposals to have a strong focus on capacity

This image of unprecedented flooding in Pakistan, which left millions vulnerable to malnutrition and waterborne disease such as cholera, was shortlisted for the Wellcome Photography Prize 2019

strengthening, to ensure that our investments enable stakeholders in countries where the research is taking place to be better equipped to undertake and use this type of research in the future.

We also launched a call on biological vulnerability to extreme heat in mothers and children, which we developed with colleagues at the Physiological Society. This aims to understand the mechanisms by which chronic exposure to excessive heat in mothers and children impacts their biology. The research teams can be based anywhere in the world.

A third call is focused on G7 countries. It is aimed at transdisciplinary research to advance the adoption or implementation of climate mitigation policies – to reduce emissions-related global warming and improve health. The policies we are interested in focus on food systems, energy, transport and housing. Applications need to demonstrate that there is a particular policy opportunity, that the research project can directly feed into the adoption of the new policy, or that it can help to improve the implementation of a particular policy. The G7 countries have been chosen because of their high levels of historic emissions, their influence on the global stage, and their moral responsibility to lead the way.

So the strategy is global in scope and focused on mitigation, placing responsibility on those with historic responsibilities to lead the way. However, it also looks at opportunities for adaptation, focussing on the countries which are going to be most affected by climate change in order to help them develop solutions that can protect their health.

We want to support emerging and developing countries to develop more sustainably. So we will be investing in sustainable development pathways and ways of growing economies which avoid locking in high levels of carbon. We are also investing in foundational data capabilities: for example, the Trust has invested in a group which will improve the ability to track health impacts of climate change through developing the capability of national statistics agencies. We will also help to convene the international community around reporting methods and standards. This work is being led by the UK ONS in partnership with the Cochrane Climate-Health Working Group and other partners and will result in ways to facilitate international comparisons.

We have funded the International Institute for Sustainable Development (IISD) to review the opportunities to integrate health into the global environment agenda. The result is a toolkit to enable those environmental sectors whose policies have an impact on health to integrate health into their priorities.

A further area of engagement was with the Lancet Countdown, which is a global project that tracks progress towards the Paris goals across 44 global indicators. Through it we have been supporting efforts to track progress, specifically in health impacts.

Finally, we are exploring how we might develop fellowships, both for policymakers and researchers. These will then be able to undertake the sort of research and action that will help us all meet our objectives to put health at the heart of climate action.

https://wellcome.org/what-we-do/climate-and-health □

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Our strategy focuses on the countries which are going to be most affected by climate change in order to help them develop solutions that can protect their health.

The debate

After the formal presentations, the speakers joined a panel to answer questions from the audience on subjects such as: exercise; lifestyle; resilience; education on health; driving forward the net zero agenda; and trade-offs.

Is it wise to encourage cycling when the environment gets very hot? In many countries that are hotter than the UK, many more people cycle than here. The main problem lies in stimulating behavioural change. Indeed, there is a more general need to change to a more Mediterranean lifestyle where physical activities are carried out at times of the day when it is cool enough. The typical sedentary lifestyle of people in the UK can also lead to severe burdens on the health service.

People are remarkably resilient, provided they feel in control of their lives. There is considerable research literature on the effects of emergencies on mental health, and this varies significantly by type of emergency and type of person. Rescue services have systems in place to deal with mental health issues among rescuers. Evidence has shown that there are net benefits to mental health from warning people of dangers and helping them prepare.

Are medical practitioners best-placed to explain the health benefits of net zero to patients? While this may be appropriate in some circumstances, others have a role too and in particular science teachers. The British Association for Sustainability and Sport has written a number of reports on the implications of climate change on sports as a way to get people to focus on the issue.

AUSDANGERGIRL, CC BY-SA 4.0, VIA WIKIMEDIA COMMONS

Short-term problems such as the energy crisis, although more immediate, can be used to drive forward net zero goals as well. Ultimately, politicians follow the cares of the general population so somehow people need to be made more aware of the personal implications of the issue.

The twin challenges of climate change and biodiversity loss are linked. However, some of the measures to tackle one can also address the other, such as reforestation.

Real efforts are being made by the health service to decarbonise and research can help it to get there faster. Straightforward actions can have immediate effect but, at some point, there will be tough choices to make, real trade-offs. Winning public acceptance for those tough choices will help maintain the political will of world leaders, who respond to public concerns. □

FURTHER INFORMATION

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CONTEXT

How can, and how should, the UK collaborate with China on R&D? That was the question which the Foundation explored at its event on 27 April 2022. The meeting discussed the current state of R&D collaboration between the UK and China and the importance of each country to the other's research community. It also explored how UK researchers and institutions needed to have a clear idea of where, and where not, to partner with China – and for this to be part of their wider strategy.

To discuss all these issues, the Foundation for Science and Technology brought together: Minister Yang Xiaoguang, Minister and First Staff Member, Embassy of China in the UK; the Rt Hon Sir Oliver Letwin, author of *China vs America: A Warning*; Vivienne Stern, Director, Universities UK; and Professor Christopher Smith, Executive Chair of the Arts & Humanities Research Council and UKRI International Champion.

A video recording, presentation slides and speaker audio from the event are available on the FST website at: **www.foundation.org.uk/Events/2022/UK–China-research-collaboration**

A relationship to benefit both parties

Yang Xiaoguang

SUMMARY

- In 1978, the UK became one of the first major Western countries to sign a science and technology agreement with China
- Bilateral trade has increased from US$300 million to $116.2 billion
- China–UK cooperation on science and technology has benefited both countries
- In an age of globalisation, China–UK cooperation on research is a must for both sides
- Research cooperation between the two countries will unlock a brighter future.

China and the UK are both permanent members of the UN Security Council. We are respectively the second and fifth largest economies in the world. Our ability to maintain the China–UK relationship bears on not only the interests of our two peoples but also world peace, stability and prosperity.

Achieving a sound relationship is not complicated: the key is abiding by the principle of mutual respect. As President Xi Jinping emphasised in his telephone conversation with the then Prime Minister in October 2021, for China–UK relations to develop, mutual trust is the foundation, mutual understanding is the precondition and proper management of differences is the key. As long as our two countries follow the principle of mutual respect and develop partnerships on an equal footing, our bilateral relations will enjoy a bright future.

This year marks the 50th anniversary of the establishment of ambassadorial diplomatic relations between China and the UK. Over the past half century, despite ups and downs, the overall relationship has kept moving forward. Bilateral trade has increased from US$300 million to $116.2 billion; two-way investment stock, which was almost zero 50 years ago, has surged to around $50 billion.

Last year, China–UK trade set a new record, and Chinese investment in the UK more than doubled. London has become the world's biggest offshore RMB trading centre. Our two countries have also coordinated well on issues such as global development and climate change, making a real contribution to tackling common challenges facing humanity.

Cooperation on science and technology is an important part of the overall China–UK relationship. With an early start, a solid basis and enormous potential, such cooperation is gaining momentum.

In 1978, China and the UK signed the Science and Technology Cooperation Agreement, making the UK one of the first major Western countries to sign such an agreement with China. In 2017, the two sides formulated the Joint Strategy for Science, Technology and Innovation Cooperation, the first between China and a Western

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Mutual trust is the foundation, mutual understanding is the precondition and proper management of differences is the key.

We are fully confident in the future of the China–UK relationship and believe that research cooperation will unlock a brighter future.

country. Now after more than 40 years of development, China–UK cooperation on science and technology has achieved remarkable results in modern agriculture, air pollution response, antibiotic resistance studies and biodiversity preservation. This has benefited the peoples of both countries and beyond.

China–UK cooperation on science and technology has never been one way. It has benefited both sides. The UK is a world leader in science and technology. It has built a solid foundation for science and is strong in original research. In China, thanks to greater input in recent years, innovation capabilities have seen notable improvement. Technologies from the UK have made an important contribution to China's development and progress, and cooperation with China has also contributed to the UK's efforts to keep and improve its research capabilities.

A recent report by King's College London shows that in British universities, more than a fifth of research on many high-impact subjects involves collaboration with China. In 2019, China and the UK collaborated on over 16,000 research papers – up from 750 in 2000.

Boosting development

China is a founding member of the Manchester-headquartered SKA Observatory and has taken an active part in promoting and supporting its development. In biomedicine and new energy, Chinese investment has boosted development in the UK. In 2021, Chinese investment added £63 billion to revenue in the UK's economy.

In an age of globalisation, China–UK cooperation on research is not optional, it is a must for both sides. No country can perform well all on its own in science and technology development. International large-scale installations, such as SKA, ITER and CERN, need the concerted efforts of many countries. In an age of big data, projects such as the Human Genome transcend national boundaries. Moreover, challenges such as Covid-19, the energy crisis, the food crisis, climate change and biodiversity loss do not respect borders. They are common problems and can only be addressed through the coordinated response of all countries, including China and the UK.

In an age of globalisation, China–UK cooperation on research is not optional, it is a must for both sides. No country can perform well all on its own.

Through years of effort, China has become an important driver for the advance of science and technology in the world. A recent Harvard University report pointed out that China has made great progress in many cutting-edge fields and is now a global leader in many areas of innovation.

Thanks to China's strategy of innovation-driven development, Chinese tech companies, both well-established and start-ups, have achieved continuous progress in a sound business environment and grown into multinational corporations with a global vision. They are globally competitive.

China is one of the first countries to realise the commercial use of 5G technology. It has been a global leader in the building and planning of 5G networks. As of today, there are 1.56 million 5G base stations in China, accounting for over 70% of the world's total. China has 40.3% of the world's 6G patent applications, the highest share of all countries.

China also leads the world on green energy technologies. It produces 70% of solar panels and 40% of wind turbines in the global market. Another field where China leads is nuclear power technology. Hualong One technology has been widely recognised, and China's 'artificial sun' holds the world record in terms of peak temperature.

In the meantime, China attaches great importance to the protection of Intellectual Property Rights, providing strong support for innovation. In just a few decades, China has established a highly efficient modern IP system. In recent years, it has topped the world in applications for both invention and patents. China ranked 12th in WIPO's Global Innovation Index 2021 and was the only middle-income economy that made the top 30.

Surveys show that 69% of US businesses in China think that IPR protection in the country has improved, and 67% of EU businesses in China think that the effectiveness of China's IPR protection laws and regulations is 'excellent' or 'adequate'.

History tells us that openness leads to progress and exclusion results in backwardness. No matter how the world might change, China remains unwavering in its confidence and resolve in reform and opening-up. China will open wider at a higher level and enhance cooperation with all countries in a joint effort to build a community with a shared future for mankind.

Against this background, we are fully confident in the future of the China–UK relationship and believe that research cooperation between the two countries will unlock a brighter future. □

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Science at the centre of the international stage

Oliver Letwin

SUMMARY

- Geo-economics is driving geo-politics
- Certain foundational technologies underly this process
- In this situation, science has moved to the heart of the geo-economic and geo-political arena
- Without continuing collaboration there is a risk of decoupling and distrust
- We must move towards an era of more sophisticated but watchful collaboration.

In contrast to some other periods of global history, we are in a time in which geo-economics is unmistakably driving geo-politics. It seems to be abundantly clear that there is a strategic rivalry between the US and China. It is essentially a question of whose grip on the world's economy will be greater, and who will out-compete whom. It is not a Cold War because it is not directly ideological strife, although there are certainly different values and governance between the two systems. At root, there is a geo-economic rivalry.

This is not unprecedented in world history. It is broadly what happened between the UK and Germany around the beginning of the 20th century. As the incumbent leader of the world's economy, the UK and its empire were challenged by the rising economic power of Germany. Rather interestingly, the rise of the US went largely unnoticed at this point. So the first point is that geo-economics is driving geo-politics rather than vice versa.

Second, certain critical foundational technologies are at the heart of this process. Of course, the industrial revolution (which resulted in 250 years of Western supremacy and led to what many in China regard as grotesque forms of humiliation over a long period) was a technological revolution. So in that sense, there are precedents. However, that was a widespread technological revolution, covering almost every aspect of industrial production. Though coal-based, the technologies were enormously various.

Today, the foundational technologies that are driving geo-economics are much more concentrated. To take one salient example, it seems clear that AI and Big Data are at the centre of the economic rivalry between US and Chinese firms. They are also at the centre of the next wave of industrial and post-industrial revolutions. The person who controls the data and who is able to exploit the data through AI, has the capacity to transform almost every aspect of human life on Earth over coming decades. This is well recognised, both in the West and in China – as well as elsewhere. Those foundational technologies are therefore central to driving geo-politics.

Third, because of the nature of these foundational technologies, science is at the heart of geo-economics and geo-politics, to a degree that has never previously been true. Basic research and the translation of basic research into more and more applied fields is fundamental to winning the geo-economic struggle and, hence, are at the centre of geo-politics.

Geo-politics

I believe that this forms the context within which to consider how far can – and should – China and the UK collaborate in research and development. To collaborate in R&D is to operate at the centre of geo-politics. It is impossible to regard this simply as an activity with scientific and humanitarian consequences.

Collaboration also has geo-economic and geo-political consequences of the greatest possible importance. Without collaboration, not just between the UK and China, of course, but between the West and China as a whole, in these foundational technologies, we will inevitably head towards increasing decoupling and a separation of economies. That means separation from the Chinese economy and influence. That direction of change is likely significantly to impoverish both China and the West.

Indeed, the rest of the world depends on the prosperity of China and the West. The poor-

The Rt Hon Sir Oliver Letwin FRSA was elected to Parliament in 1997. He served in the Shadow Cabinet for 10 years, including stints as Shadow Home Secretary and Shadow Chancellor. In Government from 2010 to 2016, he was Minister for Government Policy and Chancellor of the Duchy of Lancaster. He chaired the Home Affairs Committee and was a member of the National Security Council. A privy councillor since 2002, he was knighted in 2016. He is the author of a number of books including *China vs America: a Warning*.

The poorest people on earth depend on the continued coupling of the Chinese and Western economies to produce the growth they need.

SHUTTERSTOCK/ NOVIKOV ALEKSEY

est people on earth depend on the continued coupling of the Chinese and Western economies in order to produce the degree of growth required to improve the economic prospects for the Global South.

There is, in fact, an even bigger problem. If decoupling occurs, instead of trust, increasing distrust is bound to occur. As nations cease to collaborate with one another, they become increasingly unable to understand one another, and hence, become increasingly inclined to distrust one another. And that distrust is a very grave danger, alongside the impoverishment thatbeckons. Further, that distrust can easily lead to confrontation and ultimately to military confrontation. The history of the world is full of examples.

Therefore, the only way we stand any serious chance of managing competitive rivalries – and the geo-economic and geo-political consequences – is to ensure that there continues to be a large and growing amount of organised and sophisticated collaboration. However, each side needs to be operating with their eyes open, conscious of the likelihood that the other side might want to take advantage and so being realistic about the need for protections of various kinds. Equally, each side needs to be resilient towards the other rather than dependent.

That, of course. is a very difficult balance to strike. It is not easy to collaborate in ways that nevertheless ensure independence. There need to be safeguards that give sufficient protection from IP leakage, national security breaches and so on. Collaboration must be achieved in a way that does not involve excessive risk. That is not easy, but it is necessary.

I hope, therefore, that over the coming decades, instead of moving towards increasing decoupling, we move into an era of more sophisticated and eyes-open collaboration, gradually building increasing trust. ❑

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Each side needs to be operating with their eyes open, conscious of the likelihood that the other side might want to take advantage.

OTHER CONTRIBUTIONS

Vivienne Stern MBE, then the Director of Universities UK International (UUKi) which represents UK universities around the world, also spoke at the event. An audio record of her talk can be found at: **www.foundation.org.uk/Events/2022/UK-China-research-collaboration**

Building on a relationship of mutual respect and trust

Christopher Smith

Professor Christopher Smith is Executive Chair of the Arts and Humanities Research Council and UKRI International Champion. From 2009-2017, he was Director of the British School at Rome, the UK's leading humanities and creative arts research institute overseas. From 2017 to 2020 he held a Leverhulme Trust Major Research Fellowship on The Roman Kings: A Study in Power and held visiting positions in Erfurt, Princeton, Otago, Pavia, Milan, Siena, Aarhus and Paris Panthéon-Sorbonne.

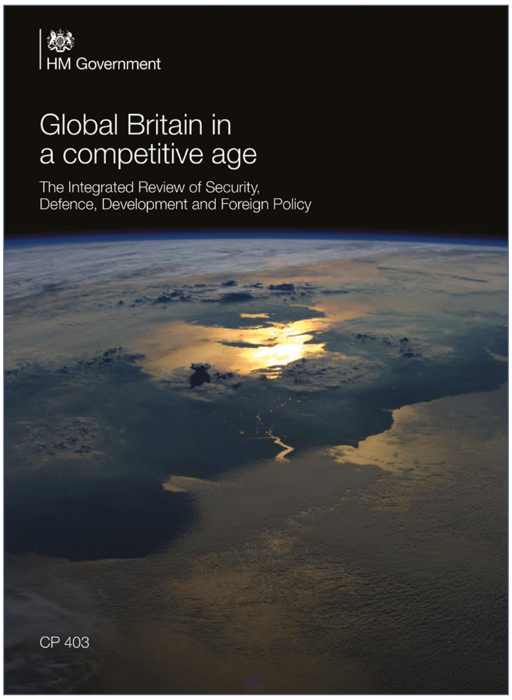
SUMMARY

- China has the second biggest expenditure on R&D in the world
- In 2020, China became the second largest partner in joint research publications with the UK, after the US
- Collaboration is built on mutual respect and trust
- Our relationship with China is long-standing and delivered through established mechanisms
- Collaboration generates benefits for the UK research and innovation community.

China's research and innovation landscape has grown enormously over the past 40 years and it is now the second biggest spender on R&D, with a year-on-year expenditure increase averaging 11.8% over the past five years. Total public and private science and technology expenditures in 2020 amounted to RMB 2.43 trillion (£276 billion) and 2.4% of GDP. China has a large and rapidly growing research base with 2.11 million researchers which is close to 25% of the world's R&D workforce.

China's rising global importance means it is becoming more important to work with, not less, even with the challenges that come from managing such enormous and accelerating partnerships. Even my own subject of Ancient History and Classics is now well represented in Chinese universities.

We enjoy a strong relationship with China on science and technology. The *Integrated Review*, a critical document for the UK, supports the position of continuing engagement with China around global challenges. In 2020, the UK became China's second largest partner in joint publications after the US. Joint papers received higher field-weighted citation indices than papers written separately for both countries. Our joint collaborative research output has more than doubled over 2016–2020.



Underpinning all of these statistics is a powerful set of collaborative relationships that are built on mutual respect and trust between universities and individual researchers in both countries. Behind this relationship is the long history of partnership with China's best researchers as well as some structural features. The UK–China Joint Strategy for Science, Technology and Innovation Cooperation was signed in 2017. There is an annual flagship challenge, where the UK and China agree to enhance levels of cooperation in a specific area and each flagship challenge lasts for about three years.

A UKRI team, based in the British Embassy in Beijing, leads relationships with China's funding agencies, facilitates the delivery of joint programmes, measures the impact of collaborations and provides a voice for UK excellence in the world's most dynamic R&D landscape. We also work with Chinese partners through a full range of multilateral international initiatives, such as CERN, the Square Kilometre Array, the Antarctic Survey and so on. This means that there is a very rich infrastructure underneath the research and innovation partnerships.

What impact does it have, though? UKRI-funded research has led to a China-wide ban on Colistin, an animal growth promoter, in order to reduce the chance of antibiotic resistance developing. This is part of a global health initia-

The *Integrated Review*, a critical document for the UK, supports the position of continuing engagement with China around global challenges.

SKA ORGANISATION

The UK works with Chinese partners on multilateral international initiatives such as the Square Kilometre Array

tive. Collaboration between China's Oxford Suzhou Centre for Advanced Research (OSCAR) and Oxford University, funded by UKRI in part, delivered Covid testing kits that work in as little as 15 minutes. New carbon capture technology, incorporated into China's existing and planned energy infrastructure, reduces the energy requirements for CO2 capture by 25-30%, delivering the goals set out in COP26. A novel battery technology is leading to the development of new fleet of hybrid buses in UK and advanced charging facilities in China. World-class expertise has been established through joint centres, such as the Centre of Excellence for Plant and Microbial Sciences, funded by BBSRC and the Chinese Academy of Sciences. All of this is both about research and about innovation, and about the combination of the two – upstream research and downstream application – for the economic benefit of society.

We do all this through the lens of trusted research. Now, there may be particular reasons to focus on trusted research and integrity in some partnerships, but it must exist in all partnerships because that is the only way to protect our researchers, their work and to ensure that it is used properly. There is significant appetite for us to continue and develop these collaborations. We will be looking to build fundamental discovery-driven research between UK and China where we can together work on critical global challenges such as health and decarbonisation, alongside other across the world.

We talk about this as if it is new. While there are particular issues at this moment in time, the relationship between the UK and China is long-standing. And the nature of our common humanity is immensely deep and is the fundamental quality upon which everything is built. I recently acquired a wonderful translation of Chinese poetry from the Tang Dynasty, the second half of the first millennium AD. It is called *In the Same Light* (translator Wong May and published by Carcanet). These poems talk about exiles, people troubled by war, people losing their homes, people falling in love, people losing loved ones, people finding peace and tranquillity in relationships with each other, and looking to the future: all written over 1,000 years ago.

These are emotions and relationships which are deep between us and on which we can build. Through the arts, humanities, science and innovation, we can build a relationship which will make us stronger together. □

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The debate

After the presentations, the speakers responded to questions and comments from the audience on a range of topics, including: areas for collaboration; risks of engagement; Government interests; and better understanding of respective cultures.

Potential growth areas for collaboration include the creative industries, tackling the challenges of climate change, green growth, health and AI.

Researchers do need to be aware of the possible risks in engaging in certain sorts of research where our own legislation prevents either voluntary or involuntary sharing of certain technologies. The key is productive collaboration where both sides have something to offer and the whole is greater than the sum of the parts. There must be actual economic beneficial effect for both parties.

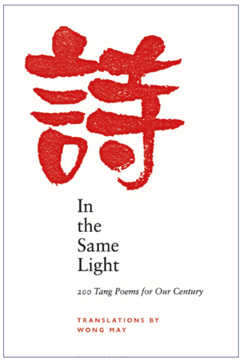
Every collaboration with an economic benefit will have a political effect. All governments therefore have an interest in economic collaboration and how this is done. It is legitimate for the Government to have an interest when leading UK companies and universities collaborate with others, so that collaboration in science and technology does not lead to being out-competed economically. Government needs the capacity and capability to do this in an intelligent way.

Does the UK need a bespoke agreement with China? The rules should surely be the same whomever you engage with? Well, all countries seek out their own interests while paying attention to those of the other side, so specific agreements are not unusual.

It was noted that there has been an alarming rise in racist abuse of ethnic Chinese staff and students in UK universities. While China goes to some trouble to understand English-speaking countries, there is a lot of ignorance in UK universities about China. The UK under-invests in promoting Chinese language skills and in research mobility from the UK to China. A strategic and long-term approach is needed, and there should be a greater emphasis on Mandarin as a modern language subject.

The pandemic has also shown us that more can be done virtually. Specific measures can help to encourage greater joint working, including collaborative PhDs with joint supervision, early career grants and fellowships. UK researchers should be encouraged to spend some time in China early in their careers.

We need to be better at gathering the data about what has (and has not) worked with collaborations, so that we are not constantly reinventing the wheel. □



FURTHER INFORMATION

In the Same Light, 200 Tang Poems for Our Century. May W (ed). Carcanet Press
www.carcanet.co.uk/cgi-bin/indexer?product=9781800172128

FST PODCASTS

R&D Collaboration with China - Podcast with Professor Dale Sanders, Director of the John Innes Centre
www.foundation.org.uk/Podcasts/2022/Dale-Sanders-R-D-Collaboration-with-China

UK/China University Collaboration – Podcast with Vivienne Stern, Director, Universities UK International
www.foundation.org.uk/Podcasts/2022/Vivienne-Stern-UK-China-University-Collaboration

Media & Journalism in China - Podcast with Professor Hugo de Burgh, Walt Disney Chair in Global Media and Communications at Tsinghua University in China and Director of China Media Centre in London
www.foundation.org.uk/Podcasts/2022/Prof-Hugo-de-Burgh-Media-and-journalism-in-China

Trusted Research and Innovation – Dr Karen Salt, Deputy Director for Research Culture and Environment, UKRI
www.foundation.org.uk/Podcasts/2022/Dr-Karen-Salt-Trusted-Research-and-Innovation

The Foundation Future Leaders programme aims to acquaint early- to mid-career professionals in Government, research and industry with different examples of science and innovation in action. This September, members of the programme, had the opportunity to travel to the Centre for European Nuclear Research (CERN) in Geneva, Switzerland. Daniel Garbutt gives his assessment.

An international focus for fundamental research

The day of the visit began with a visit to the Microcosm Exhibition, housed inside a large model – several stories in height – of an elementary particle. This exhibition gave an immersive introduction to the mission of CERN and some of the key developments in its history to date, providing a fitting primer to begin the rest of the day.

The official visit began in IdeaSquare, the innovation space for CERN. This space was quirky but functional, housing a double-decker London bus as well as various modules where ideas could be prototyped and explored.

The ideology of IdeaSquare is admirable and well-suited to unlocking the creativity around innovation, with the tagline of it being 'a place to dream'. The vision is not just to go beyond the currently impossible but to encourage the realisation of the unthinkable through innovation.

After enjoying an initial tour of the facility, the first of a series of presentations began with a description of the scientific challenges and future programmes at CERN provided by Pippa Wells, Deputy Director for Research and Computing. Pippa introduced the cohort to the four pillars that underpin CERN's mission:

- Research
- Education and training
- Collaboration
- Technology and innovation.

There are three key areas in which CERN develops technologies; these are accelerators, detectors and computing. The group was introduced to the Large Hadron Collider (LHC), its configuration and the various experiments at each of the detectors.

The largest of the detectors on the LHC is ATLAS at 44 metres long and 25 metres in diameter. It is designed to record the high-energy particle collisions of the LHC that take place at a rate of over a billion interactions per second, helping us understand the fundamental building blocks of matter, the fundamental forces of nature, and the nature of dark matter.

The Compact Muon Solenoid (CMS) is the other large general-purpose detector and is built around a large solenoid magnet. Identifying muons is one of the key tasks for this detector as they are one of the most important signatures of the Higgs-Boson. A visit to this facility was included on the day's programme, with delegates able to descend 90 metres below ground to see the data centre which has the task of collating and sorting the vast amounts of information collected during experiments.

> For the 2022 funding cycle, the UK provided the second largest input, yet the industrial returns to the UK are rated at very poor. CERN has identified that this imbalance is something it must address

The scientific priorities for the future for CERN have been drawn from the 2020 Update of the European Strategy for Particle Physics:

- Fully exploit the High Luminosity LHC
- Build a Higgs factory to further understand this unique particle
- Investigate the technical and financial feasibility of a future energy-frontier 100 km collider at CERN
- Ramp up relevant R&D
- Continue supporting other projects around the world.

Following Pippa, Brennan Goddard gave a presentation on the development of accelerator technologies for the future – highlighting the role of technology at CERN. In radio frequency accelerators, the particle gains a small amount of energy each time it passes the accelerating structure with the magnets used to steer the particle beam round the ring back to the acceleration point. The higher the energy the stronger the magnets need to be.

CERN has identified several superconducting radio frequency research and development areas, such as cavity studies, cryomodule development and power sources for radio frequency.

CERN is also developing some enabling technologies such as high-accuracy, synchronised timing solutions, radiation-tolerant electronics and various robotic technologies as well as machine learning for accelerator operation and geodetic metrology.

One of the future programmes at CERN is the high luminosity hadron collider, a one billion Swiss franc upgrade to LHC, designed to achieve a fivefold increase in the number of instantaneous collisions, enabling the experiments to enlarge their data sample by an order of magnitude compared with the LHC baseline programme.

A larger circular collider is currently at feasibility study stage. This proposed collider would provide much higher-

SIMON NAPPER

(Above) The Future Leaders group in front of a life-size image of the CMS detector at CERN; (right) members of the group being briefed by CERN staff before descending more than 80m to the level of the Large Hadron Collider.

energy collisions, achieved through a larger diameter of around 90km.

As part of the presentations at IdeaSquare the future leaders were given an understanding of the governance that enables CERN as well as the current approach to procurement.

Diversity goal

CERN's Director-General is Fabiola Gianotti, the first woman to hold this position. Some 19% of the workforce are female and it is an aim of the organisation to improve this metric over the coming years.

One of the fundamental principles that CERN has been founded upon is its use for peaceful purposes. This is a consequence of it being founded at the end of the Second World War. Europe was dealing with the aftermath of this horrific episode in its history, and this manifested itself in various initiatives for peaceful collaboration and cooperation. CERN was then founded in 1954 as a vehicle to provide world class research in particle physics and to mitigate the brain drain from a post-war Europe.

For the 2022 funding cycle the UK provided the second largest input. This totalled 14.2% of CERN's budget, yet the industrial returns to the UK are rated at very poor. This in effect means that UK businesses are not often successfully winning contracts across the organisation. CERN has identified that this imbalance is something it needs to address and is currently working with the Science and Technology Facilities Council (STFC) to improve outreach and support for UK tenders and winners.

The visit provided a striking insight into how such an historic and important multinational science project is governed, financed, technically managed and delivered. □

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CONTEXT

There has been an increasing focus on interdisciplinary research in recent years, and many current key policy challenges (including climate change, post-covid recovery, economic security, migration, and healthcare) need evidence from interdisciplinary research. In the March 2022 budget, the Government confirmed previous commitments to a significant increase to the science budget. As that budget increases, what should the UK do to increase interdisciplinary research in the UK – and what is the 'right' amount of interdisciplinary research?

To explore these questions, the Foundation for Science and Technology held an event on 18 May 2022. The speakers were: Professor Dame Ottoline Leyser, Chief Executive , UKRI; Professor Rachael Gooberman-Hill, Institute Director, Elizabeth Blackwell Institute, University of Bristol; Professor Graeme Reid, Chair of Science and Research Policy , University College London; and Professor David Soskice, Professor of Political Science and Economics, London School of Economics.

A video recording, presentation slides and speaker audio from the event are available on the FST website: **www.foundation.org.uk/Events/2022/Increasing-interdisciplinarity-in-UK-R-D**

Working together to address critical challenges

Ottoline Leyser

Professor Dame Ottoline Leyser is Chief Executive of UK Research and Innovation (UKRI) and Regius Professor of Botany at the University of Cambridge. She has worked extensively in science policy, for example serving as Chair of the Royal Society's Science Policy Expert Advisory Committee and as a member of the Prime Minister's Council for Science and Technology. She is a Fellow of the Royal Society, a Member of the Leopoldina and EMBO, and an International Member of the US National Academy of Sciences.

SUMMARY

- UKRI provides a connected framework for research in the UK
- Research anchored in specific disciplines may need additional input from other disciplines
- Challenge-led research is almost inevitably cross-disciplinary
- The separation of research and innovation is a weakness in the UK system
- We need a means of identifying and funding innovative projects that do not fit into traditional categories, neither anchored in any one discipline nor aiming to address a defined challenge.

The UK has an extraordinary track record in research and innovation, across disciplines and sectors. This breadth and depth, coupled with the UK's small geographical size, provides an opportunity to move things forward quickly through creative coordination and agility. To capture this opportunity, we have to become better at interdisciplinarity. In this context, UKRI is a crucial national asset because it brings together the disciplinary Research Councils with Research England (which provides block grants to English universities in close collaboration with equivalent bodies in the Devolved Administrations) and Innovate UK, the UK's innovation agency.

That joined-up system is exactly what is needed to support interdisciplinarity in the context of really high-quality research and innovation. However, 'interdisciplinarity' as a concept is virtually impossible to define. As a result, it is even harder to measure in a robust way. Without a coherent definition, distinct types of interdisciplinarity get lumped together, despite having very different modes of operation that need to be considered. I would highlight three classes in particular.

The place where I have the most personal experience of interdisciplinary research is where the questions are absolutely core to a particular discipline. They are not interdisciplinary questions but in order to answer them information and insights from other disciplines are needed. In my case, I worked for many years computationally modelling plant developmental biology. I had to learn to talk with mathematicians and computational scientists, so that we could build the shared language needed to address the questions I was interested in. Fortunately, they were excited about those questions too. That kind of journey takes time and effort, but it is anchored in a specific discipline.

Challenge-led research is different. Solving some of the big climate change problems, for example, will definitely need inputs from multiple disciplines. So, people come together, bringing their independent disciplinary expertise with them. Here, everybody is looking at the same problem, whereas in the earlier example, people are looking at different problems, but mutually benefiting from talking to one another.

The final category is where people are practically inventing a whole new discipline or working at the boundary between disciplines. In this case, nobody is on their home ground but is doing something new and different. This is often difficult, as much because of the sense of difficulty people experience working in unchartered territory as the reality of the barriers which do exist.

When it comes to funding, people ask questions about how to bring together the right group of people with the right mindset to assess a proposal that is interdisciplinary. Then there is the issue of publication, both getting something published in the first place, or indeed looking for other related published outputs. The issue of publication is also linked to career progression in unhelpful ways.

Where does UKRI fit into this landscape? Its vision is to build an outstanding research and innovation system for the UK, that gives everyone the opportunity to contribute and from which everyone can benefit for a whole variety of reasons, enriching lives locally, nationally, and internationally.

The interdisciplinarity toolbox

There are a number of tools at our disposal. We can convene and catalyse, as well as invest. We need to collaborate widely in order to build this thriving, inclusive system that connects different parts together, leading to prosperity and public good. The changes we are making have to do with the very things which are at the heart of the interdisciplinarity debate.

We currently have a highly-competitive system. Science (and research in general) will always be competitive: there are more good ideas than money to fund them. Yet the 'rules' for winning are currently disproportionately focussed on quite narrow criteria. That is incredibly unhelpful in terms of silo creation, because it makes people conservative and locks them into very narrow paths. The separation of research from innovation is another key weakness that emerges from current incentives. UKRI also needs to build in more capability to withstand shocks and to ensure that it is not spreading the money so thinly that everyone is clinging on for dear life. At the same time, there must be sufficient flexibility to be able to pivot if things change dramatically – as in the pandemic.

To do this requires a fundamental rethink and a focus on portfolios of different types of things, with different risk profiles that cover a full range of goals that we want to achieve, connecting elements together and building the joined-up system that we need.

UKRI has adopted four principles for change. First, diversity: of people, places, ideas. This diversity is only valuable, though, with connectivity, the second principle. Without sufficient investment in connectivity, the system will not capture the benefits of diversity. Resilience, too, is essential. Yet all of this has to come with very deep engagement, particularly societal engagement, in order to break down the barriers between wider society and the research and innovation system.

These changes are crucial to solving the challenge of interdisciplinarity. Funding and publication issues create barriers linked to assessment and consequences for career progression. We have to change the focus to support diversity, with connectivity and the different contributions that people make to collaborative activity.

The focus is not just people with very traditional research careers, but also people who may have taken very unusual routes into research and innovation, into and out of academia, industry and policy. While we need people who focus on single topics, those who jump between disciplines, or who have taken career breaks, are equally important in generating the diverse teams of researchers that we need to tackle some of these problems.

At the moment, we are too fixated on particular success measures which lock people into narrow career paths and prevent the very diversity that we need.

UKRI has introduced a Resumé for Research and Innovation (R4RI). The traditional academic CV comprises a list of papers, grants and prizes while in the resumé a narrative statement can outline contributions to knowledge, to supporting other people (be they students or colleagues), as well as contributions to the wider research community through building connectivity. This captures better the full range of the qualities and activities that we are looking for.

Projects that address challenges in a multi-disciplinary way may not, however, even reach the funders' attention because their originators have no idea where to send them. How do we 'unearth' these proposals and encourage researchers to submit them? Along with the different kinds of people we want, we need to be thinking explicitly about the fact that we are going to be funding different kinds of projects. It should be possible to develop a menu to guide the peer-review panels in how they rank proposals in a portfolio. That should be achievable with a well-devised, high-quality peer-review system.

These are some of the intersecting topics we are exploring with our communities and to which we hope to be able to apply creative solutions. □

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UKRI's vision is to build an outstanding research and innovation system for the UK, that gives everyone the opportunity to contribute and from which everyone can benefit.

Learning from the insights of others

Rachael Gooberman-Hill

Rachael Gooberman-Hill is Director of the Elizabeth Blackwell Institute for Health Research and Professor of Health and Anthropology at the University of Bristol. The Institute nurtures interdisciplinary research, including in mental health, digital health, climate change and health, and infection and immunity. Her own background is in Social Anthropology, and she leads and reflects on interdisciplinary research that aims to make a difference to people living with long-term and painful conditions.

Interdisciplinary research has a long history and provides great benefit to individuals and the research system. It can address specific challenges, can grapple with questions that could not be answered in other ways, and can develop and drive forward new methodologies. When people work across disciplines, they may have to think afresh about a number of aspects of their research, including how best to design and conduct studies; how to share information or data; and how to make research open to, and informed by, members of the public. When functioning well, interdisciplinarity enables members of the research community to share and develop their deep knowledge, insight and skills.

Interdisciplinarity takes place in the context of disciplines that are shaped by historical social and economic forces. Disciplines can have fuzzy or firm boundaries. Researchers often identify themselves through their discipline, saying: "I am a sociologist" or "I am an economist." The association between individual identity and discipline raises important questions for those working in interdisciplinary ways: people who span, or work across and between, disciplines need to feel that they are comfortable with their identities. This means making the value of interdisciplinarity clear to those already working in this way and to those who might consider doing so.

A key step in understanding and articulating the value of interdisciplinarity is to consider how we use words. Scholars have discussed at length how to define and therefore operationalise cross-disciplinary approaches, including those that are 'multidisciplinary', 'interdisciplinary' or 'transdisciplinary': roughly speaking, these reflect types of integration between disciplines. It is vital that we understand the ways in which approaches generate knowledge, but concern about which word to use or which category a particular study sits within is not always helpful. Equally, placing these approaches in a hierarchy of value or virtue may be a disservice because each has purpose and role. Although discussions about how to define approaches have a time and place, I believe that the desire to define is best balanced against a need to understand how best to encourage and enable research across disciplines.

SUMMARY

- Interdisciplinarity has a long history, wide application and needs disciplinary expertise
- Interdisciplinarity enables researchers to access insights from other disciplines
- Effective interdisciplinarity requires investment in time and energy
- Working across disciplines is as valuable as disciplinary focus
- Practical mechanisms can unlock the potential for interdisciplinarity

For all these reasons I prefer to use the term 'interdisciplinarity' in a loose way rather than worry about whether the research I describe falls into one category or another, with apologies to those for whom my laxity does not sit well.

Multi-faceted research

As an example, I lead the 'STAR' research programme, funded by the UK's National Institute for Health Research. STAR focusses on long-term pain after knee replacement surgery, which treats painful, damaged knees through their removal and replacement with an artificial joint. Unfortunately, of the 100,000 or so knee replacements each year nationally, around 15-20% of people who have this surgery are disappointed to find that they have ongoing pain afterwards. In STAR we convened a team of colleagues from a number of disciplines alongside people with experience of pain. Together we designed a multi-faceted research programme that included development and evaluation of a new healthcare pathway, work to understand why some people with pain did not come forward for treatment and studies to understand trajectories of recovery after surgery.

Openness and respect are key. Allowing time and space to have conversations means that individuals and groups can bring their own activities and approaches to the table.

Overall, team members have been pleased that STAR would help people with pain. Underpinning this success is commitment to interdisciplinarity within the programme. When asked, researchers described how the interdisciplinarity worked and what was needed to enable it. Openness and respect were key. Allowing time and space to have conversations meant that individu-

SHUTTERSTOCK/ WAVEBREAKMEDIA

The 'STAR' research programme uses an interdisciplinary approach to improve patients' experience of long-term pain following knee replacement surgery.

als and groups were able to bring their own activities and approaches to the table. Respect between members of the team and their different disciplinary perspectives is demonstrated in what people said and how they said it.

At the same time as STAR was taking place, research practices across the whole ecosystem progressed, particularly in relation to data availability and democratisation of access to research findings. As a team, we learned about these areas together, not least as 'our' disciplines looked at the issues through different lenses. As we reach the end of STAR, the research has engaged with these broader changes. For instance, in relation to data sharing, participants were able to provide their consent for sharing if they so wished and findings and data are, or will shortly be, appropriately available.

Other examples of interdisciplinarity in practice are initiatives at the Elizabeth Blackwell Institute, where I am the Executive Director. Based at the University of Bristol, the Institute receives with gratitude support from The Wellcome Trust through their Institutional Strategic Support Funding. At the Institute we develop interdisciplinary research across diverse topics.

The Institute's work to foster interdisciplinarity seems to succeed when existing organisational structures help to support individuals' desire to learn from others and to deliver research that goes above and beyond single disciplines. Sometimes we use targeted mechanisms to support interdisciplinarity. For instance, in some of our funding schemes we ask that proposals are led by, and include, colleagues from at least two of our six faculties. Other approaches are perhaps more subtle, such as workshops and events to bring the community together. Most importantly, interdisciplinarity needs to be something that people want to do and the Institute has supported myriad examples in which working across disciplines has generated research that would not have happened otherwise: from research that considered ethics and privacy in the design of technology to research bringing together fundamental science with translation and population-based approaches.

Facing challenges

It is important not to downplay or elide the many challenges in interdisciplinary research. Those with experience of it acknowledge the investment in time and energy needed, and the importance of mutual respect. There is also a need within interdisciplinary endeavours to enable researchers to feel safe, open and clear about their contributions: only by doing so can there be discussions about how best to fill any gaps in research, skills and knowledge. To provide a scaffold for interdisciplinarity, practical mechanisms can complement continued articulation of its value. Demonstration of how and why interdisciplinarity works can help to unlock further the great potential of interdisciplinary research. □

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The creativity of interdisciplinary research

Graeme Reid

SUMMARY

- Individual disciplines have an important role
- Interdisciplinary research can be a creative process
- A range of funders support interdisciplinary research
- There is no single model for successful research environments
- It would be helpful to have more role models for interdisciplinary researchers.

I want to start with a few words in defence of disciplines. Academic disciplines are cornerstones of the research ecosystem. They often provide a sense of identity for individual researchers and they provide a framework for professional training, for example in medicine, engineering or economics. They allow professionals to be trained for careers in an environment that is rich in research, where professional training and the discovery of new knowledge coexist. That coexistence of knowledge discovery and professional training is one of the many advantages of doing research in universities.

Collaborating across disciplines can be difficult. There are often differences in values, jargon, career paths and professional expertise. There are also different sources of funding and different expectations, so forming teams across disciplines comes with an administrative overhead. However, the interfaces between disciplines can be sources of creativity, allowing people with a variety of professional backgrounds to view a research challenge from distinct perspectives.

At the National Physical Laboratory, I encounter fascinating interfaces as NPL embeds very high precision measurements – often at the very limits of the laws of physics – into standards and regulation that underpin the work of businesses and public bodies right across the economy of the UK. That interplay between physics and international standards is an immensely creative process.

Ever more funders support interdisciplinary research: some have done so for many decades. Several charitable institutions and Government Departments support research that addresses interdisciplinary challenges. They want combinations of disciplines that are needed to address a problem. UKRI also has a long history of interdisciplinary work. We cannot expect UKRI alone to build a perfect interdisciplinary research environment, but it does have an important leadership role.

Then there is the question of institutional structures. Universities are wonderful places to create interdisciplinary research institutes. They have the enormous advantage of already containing a diverse population of disciplinary expertise. They can adopt an enormous variety of governance models for the structure of these institutes. They also have the agility and ability to wind down institutes and create new ones without having to fire and hire entire workforces.

Universities cannot solve every problem of interdisciplinary research, nor are standalone research institutes always the answer – indeed these institutional distinctions can be overplayed. What matters is the willingness to be agile, flexible and adventurous, not whether or not the starting point is inside or outside a university.

While disciplinary structures are a great place to train and acquire some accredited well-structured expertise in a professional domain, they can become rigid career tracks. That can be deeply unfortunate – I say that as someone who has worked across several disciplines in my own career.

One thing that would help would be the identification and promotion of more role models that demonstrate that a career as a 'discipline hopper' or an interdisciplinary researcher can be every bit as rewarding as a single-discipline career. Some wonderful role models are already available, such as a former president of the Royal Society, Lord May. I have lost track of how many careers he had as a researcher operating in different disciplines. If we find ways to celebrate them and, frankly, advertise them, that would help.

In summary, the answer does not always lie with the funding bodies. Institutional structures are important, but not always in the way we think. Simplistic categorisations like 'Institutes good, universities bad' are unhelpful. Finally, as with so many other things, a good role model goes a long way. □

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Ever more funders support interdisciplinary research: some have done so for many decades.

International approaches to interdisciplinarity

David Soskice

SUMMARY

- There are a number of key skillsets that foster innovation
- Management skills are increasingly important for success
- Software engineering is a necessity in the service sector
- Social skills are vital for working across traditional boundaries
- There is no substitute for creativity and imagination.

Working on service sector innovation in the United States and also in Germany, in Baden-Württemberg, it has been very instructive to see their approaches to fostering productive ways of working. Innovation in these countries is associated with relatively small graduate workplaces, limited management and relational decision-making.

That then has implications for the skills people need to leave university with. In my view, there are four major skill sets which interact and which foster innovation, the example here being service sector innovation. The first encompasses management skills. British universities do not focus much on these. Yet in American universities, and increasingly in German ones, management is an absolutely key skill. The second set lie in software engineering, which is a given for this sector.

The third set, which are talked about more and more nowadays, are the social, empathetic skills. Today, more than ever, people working on innovative products must have these. Fourth are creativity and imagination. It is interesting that in Germany, these skills are now being delivered by the educational system and above all by the universities. And it is not only the universities but all the research institutes, which are in essence universities of applied science closely related to the needs of the big research companies. They train people, primarily with a focus on IT, software engineering, and management. However, they pay a great deal of attention to the development of social skills through people working together; they then pick out and reward those people who have creativity and imagination.

That approach is even more embedded in the United States. In our work there, we have seen

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In some education systems, young pupils are given a project and some instruction and are left to complete it on their own, to build their collaborative working skills.

To develop a university so that it can turn out people with these sorts of skills will require very different ways of thinking.

how really good managers work. They pick out, quickly reward and promote people who they can see have creativity and imagination and, critically, who can work together with other people.

To develop a university, like the LSE, so that it can turn out people with these sorts of skills, will require very different ways of thinking. It would be possible to replicate quite a lot of what already takes place in the US and particularly in their professional schools. These are business schools but quite different from business schools here. They typically major on projects where people work together, developing just these sorts of collaborative skills which they will need in their professional careers.

Would it be possible to imagine something like this in the UK? Is it possible to imagine that in a third undergraduate year, one whole semester would consist of people working together as a group on a project which they have to solve? This is actually what Finnish children do, between the ages of six and nine. They are given a project to build a structure, are given some rudimentary instruction and then are left to complete it. This provides an environment for them to learn how to work together, to think, to choose leaders and so on.

The idea that you can train people by getting them to work together, then be able to pick out and reward those who develop these skills and, in addition, have creativity and imagination would surely be a productive way forward. □

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The debate

After the formal presentations, the speakers came together as a panel to answer questions from the audience. Topics included: UK-European approaches; non-conventional research groups; and diversity.

How does innovation, as viewed by UKRI, differ from interdisciplinarity in Europe? The culture fostered by UKRI, through its values, grants, rewards and training projects, is inherently innovative given the interdisciplinary environment it has created and within which it operates. Compared to Europe, the UK values and promotes a more interdisciplinary research culture, as opposed to a traditional way of thinking about in research. However, a comparison to European funding systems and criteria may not be entirely appropriate since one is comparing an individual country to a body made up of 28 different countries. However, ties and collaboration with Europe must be maintained.

The inclusion of non-conventional research groups, as part of interdisciplinary research projects, provides a great opportunity to bring diverse fresh perspectives and disruptive thinking into various contexts. However, non-conventional groups may sometimes lack the rigour and level of professionalism required to operate within a research system.

In order for the research and innovation system to be more inclusive, selection criteria must be amended and broadened to allow people from different disciplines to access research and thus promote interdisciplinarity. For instance, while it may be essential to bring finance as a discipline into various research contexts, the way that finance is researched academically, as compared to other disciplines, may make integration a challenge.

Diversity has a key role in an interdisciplinary environment. Even though diversity can bring forward opinions from opposing poles, these disagreements are essential in supporting interdisciplinary discourse and driving innovation. Ethnic diversity should be celebrated as it provides fresh perspectives and disruptive thinking, feeding into an ever more inclusive and constructive interdisciplinary discourse. Diversity also goes hand in hand with other essential elements that are needed to drive innovation, such as imagination, creativity, trust, respect and empathy.

Other topics raised included the recognition and reward of roles that coordinated interdisciplinarity, in a research context for instance. These roles should be recognised and rewarded as they are an essential element driving the system. Freedom of speech is important in a research context, while also protecting psychological safety in interdisciplinary environments. □

FURTHER INFORMATION

FST Podcast: Interdisciplinary research – Podcast with Professor James Wilsdon, Director of the Research on Research Institute, University of Sheffield
www.foundation.org.uk/Podcasts/2022/Professor-James-Wilsdon-Interdisciplinary-Research

CONTEXT

In April 2022, the UK Government published an Energy Security Strategy, mapping out a transition to low carbon energy sources. A key element of that is a commitment to a major expansion in civil nuclear power – to 24GW by 2050, representing 25% of projected electricity demand.

What are the challenges to achieve this target? What are the contributions from both small and large nuclear reactors? How will we develop a long-term strategy for the treatment and storage of radioactive waste.

On 15 June 2022, the Foundation for Science and Technology held an event to explore these issues. The speakers were: Julia Pyke, Sizewell C Director of Financing and Economic Regulation, EDF; Sophie McFarlane-Smith, Head of Customer Engagement, Rolls-Royce SMR Ltd; John Corderoy, GDF Technical Programme Director, Nuclear Waste Services; and Professor Paul Monks, Chief Scientific Adviser, Department of Business, Energy & Industrial Strategy (BEIS).

A video recording, presentation slides and speaker audio from the event are available on the FST website. **www.foundation.org.uk/Events/2022/New-Nuclear-and-the-UK-Energy-Strategy**

Building a new generation of nuclear power stations

Julia Pyke

SUMMARY

- Physical and economic flexibility are key characteristics for power producers
- The heat produced in nuclear power stations can be utilised for a range of purposes
- Using the same technologies and design can significantly reduce the cost of a new station
- The Regulated Asset Base model can reduce the cost of production
- When operational, the new Sizewell station will reduce costs for the consumer.

In talking about the future of nuclear in the UK, it is important to recognise that the future of the energy system is going to be predominantly intermittent and provided by renewables. So, what is the appetite for more gigawatt nuclear – providing baseload power – in an increasingly intermittent system? Early thinking about Sizewell included ways to make it economically flexible. Economic flexibility, allied to physical flexibility, has led us to the concept of an 'availability payment'. Hinkley Point C will be paid a fixed amount for putting electricity into the grid. It will not, however, be paid the same amount for, for example, using that power for hydrogen electrolysis – and this makes it economically inflexible.

In contrast, an availability payment would mean that Sizewell C will not be paid for putting megawatt hours onto the grid. It will, course, do so – up to 100% if that is what the system wants at any point in its operating lifetime – but it will be configured so that it can also put its electricity into non-grid uses. So it will be able to send its electricity, for example, to hydrogen electrolysis. Continuous power for electrolysers, alongside intermittent from renewables, increases efficiency – which is good for everybody. It also provides a use for the power when the national grid does not require that quantity of power from Sizewell. Over the 60+ year timeline for Sizewell C operation, this sort of flexibility is important.

A nuclear power station is a huge heat machine. The UK has habitually solely made electricity from this heat machine. That is not how nuclear stations have been used in other countries such as Sweden, Russia or China, where nuclear has been – or is – also used for district heating. At Sizewell, therefore, valves will be installed to take out steam at around 270°C before it hits the turbine. That will allow us to extract around $400MW_{th}$ without significantly impacting electrical output and without other changes to the design. That heat is very cheap. Obviously, there is the cost of the valves and the cost of taking the heat to where it is needed. Yet in a world in which cheap low carbon heat is at a premium, this would provide a very useful service.

Indeed, we are looking at a variety of applications for the plant. We are looking at heat-assisted electrolysis for hydrogen to make it cheaper. Sizewell is part of the Felixstowe Freeport East initiative, precisely because of its ability to provide clean

Julia Pyke is Director of Financing for Sizewell C, working with Government to identify an innovative way for Sizewell C to be funded at best value to electricity consumers, and also with potential investors and lenders to raise the capital required. Prior to her move to Sizewell C, Julia was Head of Power and Renewables for UK, US & Europe at Herbert Smith Freehills LLP. At HSF, she led a cross-practice team advising on nuclear, wind, biomass and tidal projects.

SIZEWELL C

Sizewell C will be configured so that it can put its electricity into non-grid uses such as hydrogen electrolysis.

heat and power – and hydrogen. Ports have a need for hydrogen at scale because port vehicles are often hydrogen-powered.

Another application for Sizewell energy is heat-powered desalination. Suffolk has had a very arid past year, which creates a huge issue for farmers. Using our heat output to achieve more economic desalination or other water treatment would address that issue.

We are also being funded by BEIS to develop a novel heat-powered direct air capture prototype. The prototype is being developed with Nottingham University, Strata, Atkins and Babcock. So it is a UK-developed prototype. Because it is based on heat convection, it uses almost no electricity and our 400MW$_{th}$ of heat is cheap. Indeed, the process is about half the cost of existing electricity-driven alternatives.

Reaching new investors

Many potential investors within the financial community have never invested in nuclear, but we are confident we will achieve an indicative investment grade rating for the debt, which means we will be able to raise the sums needed – in the order of £20 billion with all these new technologies and applications.

Sizewell will effectively be a second Hinkley Point. The above ground design is an exact replica. We have also agreed with Government to use the Hinkley key supply chain. It is critical to use the same key supply chain because just as we have learned, so have they. Indeed, 90% of the content of Sizewell lifetime spend will be UK supplied, which is a very impressive figure.

The Development Consent Order was issued in July. The Government has also approved the Regulated Asset Base funding model. In addition, it will take a special share in all future nuclear projects to address security concerns about nuclear power station ownership.

A big difference between gas generation and a large nuclear power station is that the latter provides energy security. As part of that, Sizewell will use fuel made in the UK. We are also looking to explore the re-enrichment of existing UK uranium stocks, which would give us close to a 100% UK supply chain as well as energy security. In addition, the electricity produced is not weather dependent.

We are often asked why nuclear is so expensive compared to wind? Well, wind power is performing a different function in the system. We are also asked how the strike price of £92.50 was arrived at? Well, £11-13 is the cost of construction. The cost of operation, including fuel and decommissioning, is around £20. The rest of the money? I started advising on this project in 2006. On the Contract for Difference model, EDF will not receive a penny until the station turns on in 2027. That represents an enormous credit card bill, some 21 years of interest on the considerable quantities of money that EDF has been spending on this power station.

Looking at Sizewell, there is an imperative to build it more cheaply. The capital cost can be reduced by using the same design again and the same supply chain. To supply safety-critical equipment into a nuclear power station, there is a very lengthy process to prove to the Office of Nuclear Regulation that the equipment can perform under high-stress circumstances. This entails a high cost to qualify the supplier but this does not need to be repeated for Sizewell C where we have the same supply chain building to the same design.

While the capital costs will be lower, the vast majority of the cost is the cost of the money. This will be lower under a Regulated Asset Base model, the model that is used for the electricity transmission system, for the water industry, the airports, etc. First, interest is not rolled up: lenders will be paid interest on their debt through construction, and the equity will receive a small return through construction.

The cost per household will be around £1 per month at the height of construction. When operational, our modelling (which uses the same basis as BEIS modelling) predicts household savings of £30-50 pounds per year. Nuclear is expensive to build as a unit item, because 7% of the nation's electricity is being constructed in two fields. But household bills will go down. This is very little understood.

Sizewell C is going to be British. We hope it will be predominantly owned by British pension funds and partly by the UK Government. EDF plans only to retain a 20% stake. In many ways, this represents an effective re-invention of UK nuclear energy capability. □

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A modular approach to a nuclear future

Sophie MacFarlane-Smith

SUMMARY

- Most decarbonisation strategies require huge amounts of low carbon electricity
- Nuclear plants generate large quantities of low carbon power very efficiently
- Light water Small Modular Reactors, such as the Rolls-Royce SMR, employ proven technology but in a manufactured modular fashion rather than as bespoke, one-off constructions
- The modular approach delivers repeatability
- The length of time taken for licensing and permitting is too long.

Rolls-Royce has been involved in the design, manufacture and operation of small nuclear plants for over 60 years as part of the UK submarine programme. It is now taking that expertise about nuclear plant design and manufacture and translating it for the civilian world.

The world has a very significant challenge with respect to decarbonisation and most solutions require electricity at vast scale. Nuclear power generates large quantities of low carbon power very efficiently. So the question is how to source more nuclear power as quickly and affordably as possible?

Rolls-Royce SMR is looking at a new way of bringing nuclear power to the market. The company believes the best way to achieve this is to use proven nuclear technology – in this case Pressurised Water Reactors – but deliver it in a different way, as a standardised manufactured product, turning it into a commodity rather than a bespoke infrastructure project.

Repeatable process

The company is not a traditional technology vendor: it will deliver the complete power station rather than just the nuclear reactor. This will be accomplished in a modularised way. That involves separating the complete package into around 1600 modules. Each of these modules has a different function and each can be transported via the road network. Importantly, this modular approach will ensure repeatability.

The company is establishing new facilities to manufacture these modules. Then they will be taken to the site where the modules will be put together to build the complete power station. This is about taking proven technology but delivering it in a new way. This makes the whole project economically viable.

Nuclear power is not just for producing electricity. Many industrial sectors need to decarbonise, not just the energy sector. The aviation industry, something that Rolls-Royce is very interested in, will need vast quantities of synthetic fuels. The marine industry will need hydrogen for all sorts of different applications. Then there is district heating and cooling, as well as technologies like direct air capture. There are many different uses for the heat and electricity that nuclear power stations can deliver reliably in vast quantities.

When talking about grid electricity, the Government and the national infrastructure operators are really important. Yet many commercial players are also looking for ways to decarbonise the industrial landscape. They have done the sums for themselves and have realised that they can only go so far with wind and solar. If they really want to decarbonise their sector, they will have to go nuclear.

Small is beautiful

This is where Small Modular Reactors – SMRs – can step in. They are smaller in size, with lower power output, and can be sited in places where large nuclear cannot fit. They can support a range of industrial sectors in their decarbonisation programmes or they can replace existing coal and gas infrastructure.

There are still challenges on the way to implementation. They are not though, about licensing. Almost every regulator in the world knows, understands and already approves PWRs. If standard fuel is used, licensing risk is particularly low. Rolls-Royce is fortunate in being a UK company

Sophie MacFarlane-Smith is the Head of Customer Engagement for Rolls-Royce SMR, with responsibility for the development of global customer opportunities and associated Government relationships. After completing a Master's Degree in the Physics and Technology of Nuclear Reactors at Birmingham University, Sophie joined the reactor physics team of Rolls-Royce in 1996. Her career in Rolls-Royce included a range of technical and project delivery roles covering multiple sectors including submarines, Naval and commercial marine and civil nuclear.

Nuclear power is not just for producing electricity. Many industrial sectors need to decarbonise, not just the energy sector.


ROLLS-ROYCE/STUDIO ARCHETYPE

Rolls-Royce is establishing new facilities to manufacture small modular reactors such as in this artist's impression.

with experience of designing nuclear plant in the UK. It understands the UK regulatory regime very well. However, it is not designing this plant just for the UK but for the world.

In regard to manufacturing, Rolls-Royce has more than 60 years' experience of making nuclear plants for the submarines programme. In addition, the company has over 100 years of manufacturing complex products for industry, not just in the UK but around the world. So we would not consider manufacturing or construction a risk, after all the plant is designed for ease of assembly. In essence, we are taking technology that is used in other sectors and bringing it to the nuclear sector. Financing, too, is not a critical issue. While £2 billion is a large sum of money, we believe it will attract investment on the open market.

So where are the major challenges? Other nuclear technologies also want to build, so we need to know very quickly which sites are available so we can get on and develop projects. We also need more sites. This is not just an issue in the UK, of course. Prospective customers – and for Rolls-Royce that includes industrial businesses – want SMRs near their own facilities, so they need more sites to be allocated.

One other factor is the need for faster site permitting. Even though a developer may have a site, and the generic licensing has been completed, there is still the obligation to go through site-specific licensing and permitting. That process takes years and does not match the speed at which the manufactured product can be deployed.

No cutting corners

To deliver in a timely fashion, there must be a way to facilitate site permitting as fast as we can manufacture. This is not about cutting corners. In the manufacturing process, there is no cutting of corners (because the result would be a product that does not work), instead it is a matter of finding the most efficient way to achieve the required result. The industry is therefore discussing with Government how to move forward with site permitting.

Then the final challenge is scale. The potential demand, within and outside the UK, to support decarbonisation and energy security around the world, is vast. The question for us is how fast can we scale up our manufacturing facilities to be able to deliver and support that demand? That is something Rolls-Royce is already starting to tackle, even as we set up our first facilities. □

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The final step – disposing of the nuclear waste

John Corderoy

SUMMARY

- The search for a permanent solution for radioactive waste has been going on since the 1970s
- Geological disposal is recognised at best practice around the world
- The current UK policy puts communities at the heart of the programme
- The first European repository for spent nuclear fuel is due to start operations in 2023
- Societies cannot abdicate responsibility for waste disposal and just hand them on to future generations.

The search for a permanent solution to the challenge of the country's growing store of higher-activity radioactive waste started in 1976, following the publication of the *Flowers Report for the Royal Commission on Environmental Pollution*. In 2022, the search continues although we are now making good progress.

The UK's inventory of radioactive waste comes from a variety of activities that trace back to the 1940s. Nor is it just a matter of the overall volume, it concerns the complexity with a huge number of different waste streams. Waste is currently stored at sites all over the country. That is not an immediate problem. But it is not fair to ask our descendants to continue to look after something that was generated 500 or 1000 years ago, which is of absolutely no use to anyone, yet incurs ongoing costs. The current effort to dispose of the waste permanently, as opposed to storing it long term, addresses the question of intergenerational equity. We should not expect future generations to carry on paying to store this waste.

There have been a number of policy papers on geological disposal. The current policy was launched in late 2018. It was developed after a thorough look at the previous process that closed in 2013. Communities are at the heart of the new approach.

The present policy is working well and it draws on international experience – what was working elsewhere. Geological disposal is recognised internationally as the only realistic choice for the disposal of large complex inventories. There are other options for less hazardous radioactive wastes, including Near Surface Disposal. Deep borehole disposal could accommodate certain waste products. However, with our inventory, when some of the packages are six cubic metre concrete boxes, they will not fit down a borehole.

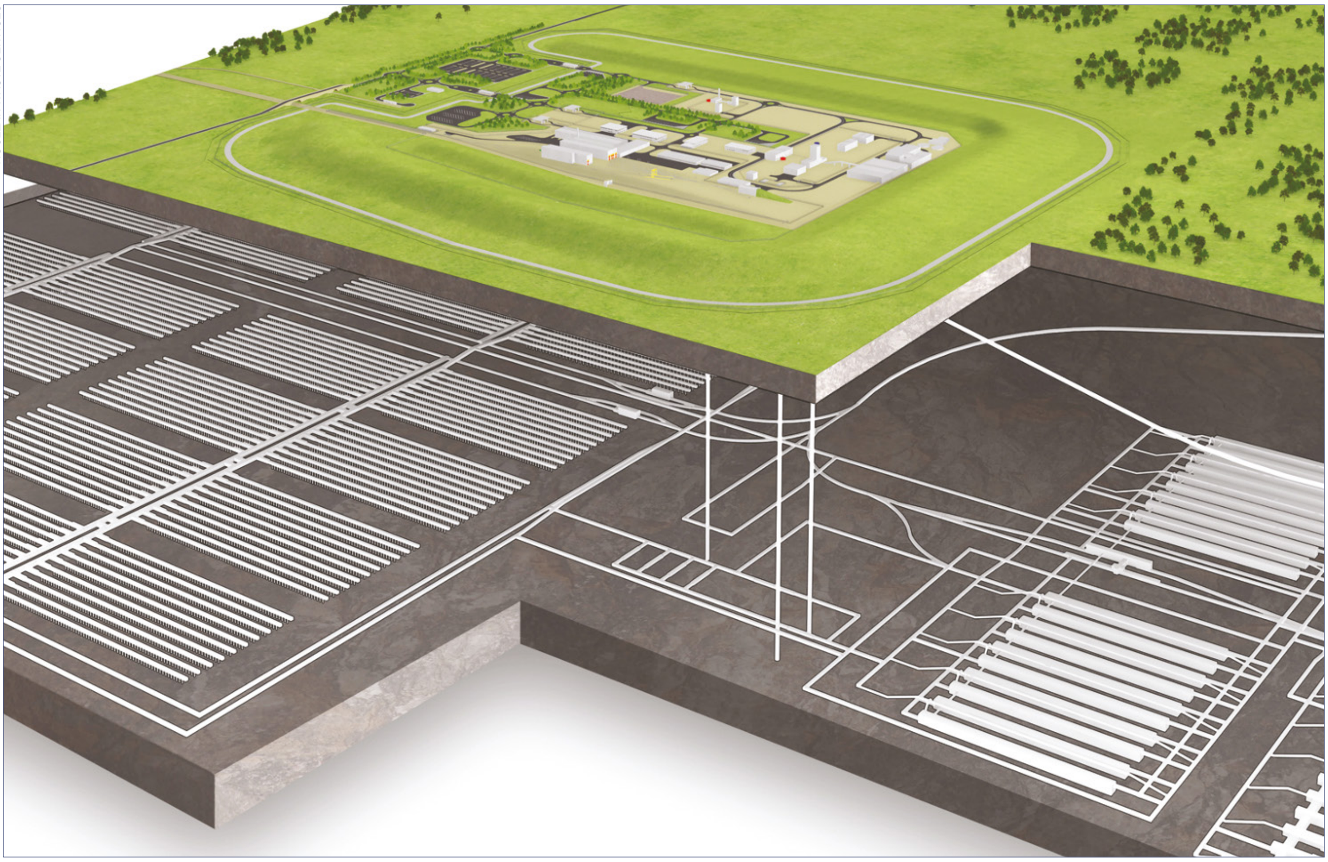
These wastes stay active and hazardous for thousands of years and some for hundreds of thousands. The Geological Disposal Facility (GDF) will use geological barriers – the facility will be up to 1000 metres deep – to provide the necessary long-term control of that waste. One option we are examining is to place the tunnels and vaults beneath the seabed. These would take up a space 5–6km square. The surface facilities on land would typically be a site of about 1km^2, a logistics facility where the waste would arrive from different parts of the country, be transferred and then moved to depth and emplaced in the vaults and tunnels. The operational phase of the GDF will be over 100 years, after which the whole facility will be sealed up. That is, in essence, what a deep geological repository is all about.

We work very closely with other international waste management organisations. Finland has constructed the initial parts of its repository. Final commissioning work will take place in 2023 and then disposal of Finland's inventory of spent fuel will begin. Sweden is not far behind and then the French programme, which should be in operation towards the end of this decade. Canada is just completing a long site-selection process, with 22 volunteer communities. They are close to making their final choice

So the UK is in good company. As the nation that started the Atomic Age, though, we really need to push on ourselves. If we can close the back end of the fuel cycle with a permanent disposal solution that removes the liability from

John Corderoy is the GDF Technical Director for Nuclear Waste Services, the delivery body for the UK's deep Geological Disposal Facility (GDF), which will provide a final disposal route for the UK's higher activity radioactive waste. He has responsibility for all technical aspects associated with delivery. Previously, John had a 30 year career with the Royal Navy as a nuclear submariner; and as the UK's Director of Nuclear Propulsion he was responsible for all aspects of designing, delivering and supporting submarine reactor plants.

It is not fair to ask our descendants to continue to look after something that was generated 500 or 1000 years ago, which is of absolutely no use.



NUCLEAR WASTE SERVICES

Illustrative example of a Geological Disposal Facility (GDF).

future generations, then I think we are doing a really good thing.

Energy security

The Energy Security Strategy sets out an aspiration for 24GW of new nuclear capacity. The 2014 policy paper already assumed 16GW to be accommodated in our programme, along with a number of other items that are still in debate as to whether they represent wastes or not – things like depleted uranium. So there was already a large inventory underlying our planning.

It should also be noted that the design of the GDF is modular. It is not a matter of building the entire structure and then filling it. Just like a mine, it evolves over the 100 or more years of its lifetime, with the tunnels and vaults being built as they are needed. So 24GW is not a specific challenge for a GDF. In addition, we are at the early part of the design programme, so it is easy to accommodate that type of change.

There are now four communities in the process, with three in West Cumbria which has a strong history in nuclear. Then there is Theddlethorpe on the East Coast which is our first non-nuclear community. We are currently in discussion with those four communities and carrying out some initial geological investigations. We will look to pick the two front runners in 2025 or 2027. Then there will be a programme of intensive geological investigation before selection of our preferred site. Discussions with the communities can be quite complicated given the range of views and aspirations. This facility will however provide long term jobs, and some tangible socio-economic benefits quite quickly.

In terms of national infrastructure, though, it is essential. It is a key part of the Nuclear Decommissioning Authority's overall mission and is part of the largest environmental clean-up programme in the UK. So it is an immensely worthwhile project to be engaged in.

Informed consent

One of the key lessons from the past 40 years is that whenever organisations or Government have tried to enforce this on an area, it has not worked. That is not just a UK experience, there is plenty of evidence globally. This time, communities are at the heart of the process.

One of my pleas to the whole of the nuclear sector is to have a little patience. We fired the starting gun in the UK in 1976. People often ask if I can shorten the timeline by a year or two to get to first waste emplacement. Actually, the most important factor is building that trust with the communities, carrying them over the line and really getting them invested in an enterprise that they will be proud to host and be part of, for a very long time. □

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Nuclear's part in a net-zero future

Paul Monks

Professor Paul Monks BSc DPhil FRMetS FRSC is Chief Scientific Adviser (CSA) for the Department for Business, Energy and Industrial Strategy (BEIS). His role is to deliver independent and impartial scientific advice to Ministers and policy makers. Prior to joining the department, Professor Paul Monks was Pro-Vice Chancellor and Head of the College of Science and Engineering at the University of Leicester, where he remains a Professor in Atmospheric Chemistry and Earth Observation Science.

SUMMARY

- By 2050, most of the UK's energy will come from renewable sources
- Because of its variability, there will need to be a way to load-balance using low carbon energy and storage
- Nuclear energy can meet that need
- Nuclear can also provide large quantities of heat for a variety of applications
- One of the challenges will be ensuring sufficient skilled people and researchers to deliver this agenda.

To achieve net zero by 2050, the UK needs to decarbonise its economy, the starting points for which will include reducing demand and increasing the efficiency with which we use energy. There are a number of low carbon solutions available and co-generation is high on the list. Indeed, it is low carbon energy that is important, rather than just electricity, which only accounts for 17% of total energy demand. For comparison, about 40% of the total energy supply is used in transport and 43% in heating.

The British Energy Security Strategy (BESS) speaks about significant investment in new nuclear, but it is not possible to discuss the role of nuclear without thinking about what the rest of that system looks like. The more renewables on the system, the greater the variability. How then, on a winter's day, can 7TWh of supply be guaranteed? It is forecast that the UK will need to double the amount of electricity as we decarbonise.

The story of BESS started in November 2020 with a template for the Green Industrial Revolution. In October 2020, as part of efforts for COP26, the Government produced the Net Zero Strategy for the UK, which the Committee on Climate Change has described as one of the most comprehensive strategies ever produced by a country. The invasion of Ukraine by Russia then focussed minds on the scale of the ambition, which was brought together in BESS.

This was published as a package of ambitious measures for a secure, clean, and affordable energy system. The Strategy includes an aspiration for 24GW of new nuclear by 2050, which would account for 25% of our projected energy needs. To achieve that, the Strategy establishes Great British Nuclear as the new delivery body for this technology.

However, the Strategy also considers the next generation of nuclear beyond gigawatt stations and has set up the Future Nuclear Enabling Fund. Other ambitions in the Strategy will help drive a more rapid decarbonisation of our energy system by 2050 and address the demands of changing energy usage. For example, financial models will have to change in order to achieve the required investment in nuclear.

It is not just about building power plants, it is also the way the system as a whole operates in the future. We currently have plans for gigawatt stations and for Small Modular Reactors (SMRs). Looking beyond that, Advanced Modular Reactors (AMRs) are the next generation of small reactors, designed to take forward the promise of cogeneration. In the longer term, there is nuclear fusion and BEIS has been taking this forward through the STEP (Spherical Tokamak for Energy Production) process.

Regarding AMRs, the High Temperature Gas Reactor is our preferred solution as the AMR RD&D programme makes clear. Gas reactors are a well-understood technology, the UK supply chain is familiar with them and has the skills to deliver them. This is existing technology which will need some enhancement. This may take the best part of 20 years, but it is still only changes to an existing technology.

Cogeneration is a critical part of this story. Some 65% of the energy created in a nuclear station is wasted as heat, yet this is a commodity. As we decarbonise, we must become much more efficient in the way that we use that heat.

In the new energy system, base load will be created, essentially, by renewables. Nuclear will be used to balance the load. However, to do so, we will have to invert the accepted way of doing things. There are many other applications for nuclear energy, such as hydrogen production, direct air capture, seawater desalination, and making ammonia for maritime uses.

BEIS has been working on the role of R&D in

It is not just about building power plants, it is also the way the system as a whole operates in the future.

this area. One of the key challenges will be finding the right people to deliver this programme. There will be a need for skilled people who know how to do nuclear operations, who can research the science and build the plant. There are generations of jobs here. At the same time, it should not be forgotten that some of these skills have been lost as that specialist group of workers has aged and retired. This country will have to make sure it trains the people, delivers the skilled workforce needed and funds the R&D that gives longevity to the nuclear programme.

In terms of cost, there is a tendency to think about nuclear in the wrong way. This must be put in the context of the system cost of electricity, not only the generation cost. We spend billions on load balancing per annum, but that is not yet thought of as a primary cost of the electricity system. We must think about the levelised cost of the total system. Nuclear offers a trade-off between capacity and generation.

The British Energy Security Strategy sets out the scale, magnitude and speed of the Government's ambition in this area. There is no harm in pushing hard and fast to decarbonise our economy in a world that needs it. □

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The debate

After the formal presentations, the speakers responded to questions from the audience on a variety of subjects, including: SMRs; skills and jobs; climate change; and financial factors.

Is it realistic to expect communities to accept SMRs in particular and nuclear more generally? Demand from industry is growing for low-carbon power and industry will come to where that power is. Communities are interested in the jobs that come with that. A non-nuclear community is already engaged in discussions about hosting a Geological Disposal Facility.

There is a majority of the population in favour of nuclear. Many younger people are joining the nuclear industry as they see it as a green technology. The number of staff needed by SMRs compared with gigawatt stations is broadly proportional to size. A key issue is that, with an expanding nuclear industry, there is a significant training requirement, although there should be time to address that.

The Green Task Force is working on the jobs needed for the net zero transition, including nuclear. One element which may help with skills shortages is to promote cooperation rather than competition across the nuclear industry. Yet skills will remain an issue and we need to increase our ambition in delivering certain key high-end skills – not just in nuclear engineering but also in high-end construction.

There are many things that the nuclear industry can learn from other sectors, particularly shipbuilding and defence. There are also potential opportunities internationally in being a leader in nuclear decommissioning. Nuclear fusion is an area with real UK strength. There is, too, plenty of technology which can transfer over from an SMR to a small fusion reactor.

Climate change needs to be considered in the design and siting of nuclear power stations and the GDF. It has indeed been a key part of the design of a GDF, including the potential for rising sea levels. The GDF itself would also be based on low carbon construction methods and materials. A single GDF should be sufficient for the UK's needs for well over 100 years.

Nuclear still needs to become a better proposition for the investor community, which has seen previous nuclear projects significantly over budget and behind schedule. The Government has announced that it is minded, subject to consultation, to give a Regulated Asset Base (RAB) licence to Sizewell C. The project will have investment grade debt, and similar commercial risk characteristics. In terms of the equity, the model has a capped upside and a capped downside. It should therefore produce an extremely predictable long-term return. □

FURTHER INFORMATION

British Energy Security Strategy (HM Government, April 2022)
www.gov.uk/government/publications/british-energy-security-strategy/british-energy-security-strategy

FST PODCASTS

Sizewell C and New Nuclear Power – Podcast with Dr Mina Golshan, Safety, Security and Assurance Director at Sizewell C
www.foundation.org.uk/Podcasts/2022/Dr-Mina-Golshan-Sizewell-C-and-new-nuclear-power

UK Energy Strategy – Podcast with Dr Doug Parr, Chief Scientist and Policy Director, Greenpeace UK
www.foundation.org.uk/Podcasts/2022/Dr-Doug-Parr-UK-Energy-Strategy

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An Innovation Strategy for Scotland
7 November 2022

Ivan McKee MSP, Minister for Business, Trade, Tourism and Enterprise, Scottish Government
Dr Deborah O'Neil PhD OBE FRSE, Chief Executive Officer, Novabiotics
Professor Sir Jim McDonald, Principal and Vice-Chancellor of the University of Strathclyde, and President of the Royal Academy of Engineering
Professor Julie Fitzpatrick OBE, Chief Scientific Adviser for Scotland
Professor Rick Delbridge, Professor of Organisational Analysis, Cardiff Business School, Cardiff University

Leadership in Tomorrow's World - Foundation Future Leaders Conference 2022
1 November 2022

Science, Climate Policy and COP27
26 October 2022

Sir Patrick Vallance, UK Government Chief Scientific Adviser
Professor Mahmoud Sakr, President, Egyptian Academy of Scientific Research and Technology
Emma Howard Boyd, Chair of the Green Finance Institute
Professor Jim Skea CBE, Chair in Sustainable Energy, Imperial College & , Co-chair of Working Group III of the IPCC

Health policy implications of climate change
13 July 2022

Professor Chris Whitty KCB FMedSci, Chief Medical Officer for England
Professor Mike Tipton MBE, Trustee, The Physiological Society, and Professor of Human and Applied Physiology, University of Portsmouth
Dr Modi Mwatsama, Head of Climate Interventions, Climate and Health, Wellcome Trust

Scenarios for a Science Superpower
6 July 2022

Professor Sarah Main, Executive Director, Campaign for Science and Engineering
Professor Graeme Reid, Chair of Science and Research Policy , University College London
Lisa Brodey, Science Counselor, US Embassy London
The Lord Rees of Ludlow OM Kt FRS, House of Lords

New Nuclear and the UK Energy Strategy
15 June 2022

Julia Pyke, Sizewell C Director of Financing and Economic Regulation, EDF
Sophie Macfarlane-Smith, Head of Customer Engagement, Rolls Royce SMR Ltd
John Corderoy, GDF Technical Programme Director, Nuclear Waste Services
Professor Paul Monks, Chief Scientific Adviser, Department of Business, Energy & Industrial Strategy

Increasing interdisciplinarity in UK R&D
18 May 2022

Professor Dame Ottoline Leyser DBE FRS, Chief Executive , UKRI
Professor Rachael Gooberman-Hill, Institute Director, Elizabeth Blackwell Institute, University of Bristol
Professor Graeme Reid, Chair of Science and Research Policy , University College London
Professor David Soskice FBA, Professor of Political Science and Economics, London School of Economics

UK-China research collaboration
27 April 2022

Minister Yang Xiaoguang, Minister and First Staff Member, Embassy of China in the UK
Rt Hon Sir Oliver Letwin FRSA, Author of *China vs America: A Warning*
Vivienne Stern MBE, Director, Universities UK International
Professor Christopher Smith, Executive Chair of AHRC and UKRI International Champion

Rebuilding the UK Electricity Grid
23 March 2022

Nick Winser CBE FREng, Chairman, Energy Systems Catapult
Dr Cathy McClay OBE, Trading and Optimisation Director, Sembcorp Energy UK
Professor Keith Bell, Scottish Power Professor of Smart Grids, University of Strathclyde

Delivering the AI Strategy – the use of new AI technologies in industry and the public sector
23 February 2022

Professor Dame Wendy Hall DBE FRS FREng, Regius Professor of Computer Science, University of Southampton
Lord Clement-Jones CBE, House of Lords
Professor Geraint Rees FMedSci, Pro-Vice-Provost, AI, University College London
Professor Tom Rodden, Chief Scientific Adviser, Department for Digital, Culture, Media and Sport

How can the National Science and Technology Council and the Office for Science and Technology Strategy direct S&T priorities?
26 January 2022

Sir Patrick Vallance FRS FMedSci FRCP, National Technology Adviser & Government Chief Scientific Advisor
Professor Dame Ottoline Leyser DBE FRS, Chief Executive UKRI
Naomi Weir, Programme Director - Innovation, Confederation of British Industry
Professor James Wilsdon, Director, Research on Research Institute, University of Sheffield

Round Table on UK Technology Priorities
26 January 2022

Andrew McCosh, Deputy National Technology Advisor and Director General of the Office for Science and Technology Strategy

COP26: where do we go from here?
1 December 2021

The Lord Broers, House of Lords
Professor Sir Dieter Helm CBE, Professor of Economic Policy, University of Oxford
Professor Sir Ian Boyd FRSE FRSB FRS, Professor of Biology, University of St Andrews
Baroness Young of Old Scone, House of Lords
Professor Sir Charles Godfray CBE FRS, Director, Oxford Martin School, University of Oxford

EU R&D Programmes – Round Table
24 November 2021

Foundation Future Leaders Conference
22-23 November 2021

Rt Hon Greg Clark MP, Chair, House of Commons Science and Technology Select Committee
Dr George Dibb, Head of the Centre for Economic Justice, IPPR
Baroness Brown, Climate Change Committee
Dr Doug Parr, Chief Scientist, Greenpeace
Dr Hayaatun Sillem CBE, Chief Executive, Royal Academy of Engineering
Professor Melanie Welham, Executive Chair, BBSRC
Indro Mukerjee, Chief Executive, Innovate UK
Dr Peter Waggett, Director, IBM UK

EVENTS

The UK Innovation Strategy
13 October 2021
Rt Hon Kwasi Kwarteng MP, Secretary of State for Business, Energy and Industrial Strategy
Indro Mukerjee, Chief Executive, Innovate UK
Dr Hayaatun Sillem CBE, Chief Executive, Royal Academy of Engineering
Paul Stein FREng, Chief Technology Officer, Rolls Royce
Priya Guha MBE, Partner, Merian Ventures

Science & Public Policy - Developing Systems for Science Advice to Governments and Parliaments
23 September 2021
Louise De Sousa, British Ambassador to Chile
Dr Andrés Couvé, Science Minister of Chile
Gavin Costigan, Chief Executive, Foundation for Science and Technology
Professor Carole Mundell, Chief International Science Envoy , Foreign, Commonwealth and Development Office
Dr Olga Barbosa, First Regional Secretary, Chilean Ministry of Science
Dr Stuart Wainwright, Director, Government Office for Science
Professor Kristiann Allen, Executive Secretary, International Network for Government Science Advice
Leonardo Muñoz, Head of Science and Government, Chilean Ministry of Science

The future of European Space Policy
15 September 2021
Josef Aschbacher, Director General, European Space Agency
Dr Alice Bunn, Chief Executive, Institution of Mechanical Engineers
Sir Martin Sweeting, Group Executive Chairman, Surrey Satellite Technology
Paul Bate, Chief Executive, UK Space Agency

Lessons from the Vaccine Programme for UK Life Sciences
19 July 2021
Nadhim Zahawi MP, Minister for Covid Vaccine Deployment
Professor Dame Sarah Gilbert DBE, Saïd Professorship of Vaccinology, Jenner Institute, University of Oxford
Steve Bates OBE, Chief Executive Office, BioIndustries Association

Developing a Systems Approach to reaching Net Zero
28 June 2021
Professor Sir Jim McDonald FRSE FREng FInstP FIET, Principal and Vice-Chancellor of the University of Strathclyde, and President of the Royal Academy of Engineering
Dervilla Mitchell CBE, Joint Deputy Chair, Arup
Guy Newey, Strategy & Performance Director, Energy Systems Catapult
Colette Cohen, Chief Executive, OGTC

Biodiversity: Economics, Science and International Action
24 May 2021
Professor Sir Partha Dasgupta FRS FBA, Professor Emeritus of Economics, University of Cambridge
Professor Yadvinder Malhi CBE FRS, Professor of Ecosystem Science, University of Oxford
Dr Stephanie Wray, Managing Director, Nature Positive, and former President of the Chartered Institute of Ecology & Environmental Management

The future of clinical trials regulation in a post-Brexit UK
30 April 2021

The Effect of the Coronavirus Lockdown on the Mental Health of Children and Young People
24 March 2021
Professor Cathy Creswell, Professor of Developmental Clinical Psychology, University of Oxford
Lea Milligan, Chief Executive, MQ Mental Health Research
Gregor Henderson, National Lead, Mental Health and Wellbeing, Public Health England

Will Hydrogen Technologies get us to Net Zero?
24 February 2021
Nigel Topping, High Level Climate Action Champion for UN climate talks, COP26
Baroness Brown of Cambridge DBE FREng FRS, House of Lords and Deputy Chair, Committee on Climate Change
Jane Toogood, Chief Executive, Efficient Natural Resources, Johnson Matthey

Creating a 'UK ARPA' – and making it a success
27 January 2021
The Rt Hon Greg Clark MP, Chair, House of Commons Science and Technology Committee
Dr Ruth McKernan CBE, Former Chief Executive, Innovate UK
Felicity Burch, CBI Director of Innovation and Digital, Confederation of British Industry

Nuclear Cogeneration and Net Zero
9 December 2020
Professor Robin Grimes FRS FREng, Professor of Materials Physics, Imperial College
Jo Nettleton, Deputy Director and Head of Radioactive Substances and Installations Regulation, Environment Agency
Duncan Hawthorne, Chief Executive Officer, Horizon Nuclear Power

Online Teaching in Higher Education post-Covid
25 November 2020
Michelle Donelan MP, Minister of State for Universities
Dr Paul Feldman, Chief Executive, JISC
Professor Sarah Speight, Pro-Vice-Chancellor, Education and Student Experience, University of Nottingham

Science, Technology & Research in Universities – Foundation Future Leaders Conference
17-19 November 2020

Future Priorities for UKRI
2 November 2020
Professor Dame Ottoline Leyser DBE FRS, Chief Executive , UKRI
Professor David Paterson, Head of the Department of Physiology, Anatomy & Genetics, University of Oxford
Priya Guha, Venture Partner, Merian Ventures

Skills Resilience in a Changing World
21 October 2020
Ben Fletcher, Executive Director of Policy & Engagement, MakeUK
Austen Okonweze, Deputy Director, Engagement & Planning, Industrial Strategy, Department of Business, Energy & Industrial Strategy
Elizabeth Crowley, Skills Adviser, Chartered Institute of Personnel & Development

The R&D Roadmap – Levelling Up Across the UK
7 October 2020
Amanda Solloway MP, Minister for Science, Research and Innovation, UK Government
Professor Richard Jones FRS, Chair of Materials Physics and Innovation Policy, The University of Manchester
Ken Skates MS, Minister for Economy, Transport and North Wales, Welsh Government

Science and politics: how to bring them together, and keep them apart
15 July 2020
Professor Sir Mark Walport FRS HonFRSE FMedSci, Chief Executive, UK Research and Innovation (UKRI)
Professor Sir David King ScD FRS HonFREng, Chair of Independent SAGE
Professor Dame Angela McLean DBE FRS, Chief Scientific Adviser, Ministry of Defence

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