fst journal

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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

COUNCIL AND TRUSTEES

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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Gaia space observatory reveals new maps of the Milky Way

The third data release from the Gaia space observatory has revealed new details on nearly two billion stars in our galaxy.

Gaia is an international mission led by the European Space Agency (ESA) to create a 3D map of the Milky Way. Its new findings offer the largest-ever catalogue of data for objects in and beyond our galaxy.

The data provides a multidimensional map of stars, moons, asteroids, quasars and galaxies, and UK-built technologies such as components of its 1-billion-pixel camera are crucial to Gaia instruments.

Key to Gaia's success are its scientific instruments developed by experts across the UK, supported by investment from the Science and Technology Facilities Council (STFC) and UK Space Agency.

Gaia's data release three has recorded details including: chemical compositions; stellar temperatures; colours; masses; ages; and the speed at which stars move towards or away from us (radial velocity).

The new data release also includes Gaia's first major release of spectroscopy data, that measures the absorption and splitting of starlight.

www.esa.int/Science_Exploration/Space_Science/Gaia

First UKRI review

The Department for Business, Energy & Industrial Strategy (BEIS) has published an independent review of UK Research and Innovation (UKRI), led by Sir David Grant. Launched in April 2018, UKRI is the Government's primary funder of research and innovation. It includes the seven disciplinary Research Councils; Research England, which is responsible for supporting research and knowledge exchange at higher education institutions in England; and Innovate UK, the UK's innovation agency.

This is the first review of UKRI since its creation, and follows the publication of UKRI's first five-year strategy. Ministers and the UKRI leadership have expressed their support for the review's 18 recommendations, which include investment in harmonising IT systems, clarifying roles and responsibilities within UKRI and with BEIS, as well as a further focus on demonstrating outcomes from their funding.

www.gov.uk/government/publications/independent-review-of-uk-research-and-innovation-ukri

ARIA appointments

The Government has appointed Ilan Gur as Chief Executive of the UK's Advanced Research and Invention Agency (ARIA). His role will be to set the agency's agenda, direct its initial funding of high-risk programmes, build the team of Programme Managers and engage the domestic and international R&D sector.

It has also announced the appointment of talent investor and entrepreneur Matt Clifford as ARIA's Chairman. He will support the work of the CEO, acting as the steward for ARIA's effective governance.

Programme aims to build public trust in AI

A new research programme has been announced that will see researchers collaborate with industry and policymakers to tackle some of the of the biggest ethical questions posed by artificial intelligence (AI).

The £8.5 million programme aims to build public trust and ensure the UK remains at the global forefront of the research, development and deployment of AI technology. The *Enabling a Responsible AI Ecosystem* programme is led by the Arts and Humanities Research Council (AHRC), part of UKRI, and will be delivered in partnership with the Ada Lovelace Institute. The programme will move beyond AI ethics frameworks, creating recommendations and using case studies that can be put into practice for a range of AI applications, including:

- biometrics and facial recognition;
- big data analytics in the financial sector;
- diagnostics in healthcare.

Harnessing the expertise of researchers and innovators from a range of disciplines, from the humanities to computer science, the programme will involve diverse perspectives to tackle these complex ethical challenges.

How can Government regulate innovation?

The Regulatory Horizons Council (RHC) has set out how the gap can be closed between existing principles for innovation-friendly regulation, and how they are applied in practice.

The RHC is an independent expert committee set up to identify the implications of technological innovation and advise on appropriate reforms to its regulation.

RHC chair Cathryn Ross said: "We have found that while regulation can be a barrier to innovation, when it is done right it can be a key enabler. Our research uncovered a number of gaps between current regulatory practice and what needs to happen to enable the rapid and safe adoption of technological innovation."

The report was commissioned by Business Secretary Kwasi Kwarteng in line with the UK's Innovation Strategy. The Council outlines six focal points in its report:

- regulation should adopt a proportionate approach to benefits and risks;
- regulation and innovation should embrace ethics and public engagement;
- regulation should take account of commercial considerations and the need to attract investment;
- regulatory design and implementation should consider alternative forms of regulation;
- regulation must get the timing right;
- regulators should foster a culture of openness and a growth mindset.

The report highlights that innovation does not occur in isolation, and that a collaborative effort from Government, regulators and innovators is the best way to foster an environment that supports and promotes innovation.

www.gov.uk/government/publications/closing-the-gap-getting-from-principles-to-practice-for-innovation-friendly-regulation

GUEST EDITORIAL

In the last issue of FST Journal, Science Minister George Freeman MP set out the Government's approach to UK science in a global marketplace and outlined his own objectives in this area as a Minister. Here, Chi Onwurah MP offers a critique of current policy from an Opposition viewpoint.

Science and technology at the heart of a successful economy

Chi Onwurah

I believe in science for science's sake. It is part of our innate humanity to seek to push forward the boundaries of knowledge. Here in the UK we have a fantastic, world-leading scientific tradition. From Isaac Newton to Stephen Hawking, Ada Lovelace to Rosalind Franklin and, of course, Newcastle-born Peter Higgs – discoverer of the Higgs boson.

The Covid-19 pandemic made clear the value and strength of British science, with a vaccine that is used across the world created in labs in Oxford. Having worked in tech for 20 years as a Chartered Electrical Engineer, I am particularly proud that the UK is at the cutting edge of so many disciplines which are shaping our economy and our wellbeing – life sciences, AI and quantum computing, to name a few.

Mission critical

Our current Government may try to talk a good game on science. We have all heard the soundbites 'science superpower', science is 'the great liberator', the UK is 'world-beating' on science. Yet all too often the reality on the ground for scientists, researchers, entrepreneurs and those whose wellbeing depends on scientific breakthroughs is that the Government is not serious about science: whether that be supporting UK science to grow and prosper, or driving policy by evidence and reason.

Science, research and development are by their very nature long term endeavours: they require vision and a long-term plan. This Government, however, struggles to think beyond next week. It stumbles from crisis to crisis, scandal to scandal, and this undermines the science sector.

Just look at the record. We are on our fifth change of Science Minister in less than three years – never mind a long-term plan for science, it would be nice to have a long-term Minister. Each Minister introduces their pet projects, leaves, and then another comes in to try and reinvent the wheel. We have had an 'Innovation strategy', an 'R&D roadmap', a 'science plan', an 'Office for Science and Technology Strategy,' 'grand challenges', 'industrial strategies', 'sector deals', 'accelerators', 'cluster innovation accelerators' the Advanced Research and Invention Agency (ARIA) and two re-organisations of UKRI. A 'science superpower' requires purpose, power, resources and leadership. British science is being badly let down on each count.

The Government's failure on science hurts not just the science community but our wider economy. Science and technology are the engine of a high skills, high wage, high productivity economy. We need innovation to drive the technologies and production processes of the future and deliver a just transition to a green economy. We need major investment now, all across the country, to turn the overlapping challenges of rising global temperatures, an ageing population and automation into opportunities for all in this United Kingdom.

Under the Conservatives, we have had over a decade of failure on innovation, discovery, and growth. That British science has continued to succeed is a testament to our world-beating scientists and science infrastructure – but imagine how much further forward we could have been with competent, consistent Government. For example, the UK has lost a significant amount of its world-leading pharmaceutical manufacturing capabilities – vital for drug and medicine development – and the Government has not taken the steps to retain or rebuild it, even after Covid.

There is also a significant geographical inequality of science and research spending. The North receives less than half of the lifescience investment per head that the South of England gets – despite having great teaching hospitals and significant health inequalities. Investment by Government totals just £22 per person in the North, two fifths of the £56 per person invested in the South of England. In the Midlands, it is as low as £16.

As the Campaign for Science and Engineering said, the UK's R&D strategy is all £s and no peo-

Chi Onwurah is the Shadow Minister for Science, Research and Innovation and the MP for Newcastle Central, first elected in 2010. She is a chartered engineer with a degree in Electrical Engineering from Imperial College and an MBA from the University of Manchester. Before she entered parliament, she worked as a telecommunications engineer in the UK, France, US, Nigeria and Denmark before becoming head of Telecoms Technology for Ofcom. She has been on the Labour frontbench since 2010, focussing on aspects of science and technology policy. She is a former trustee and current Council member of the Foundation.

The Government's failure on science hurts not just the science community but our wider economy. Science and technology are the engine of a high skills, high wage, high productivity economy.

Key to becoming a science superpower will be developing the UK's capacity to turn ideas and invention into commercial usage and protecting key industries and assets from foreign hostile takeovers.

ple. CaSE highlights underinvestment, unchallenged stereotypes and uninspiring courses which result in many young people being put off STEM subjects from an early age, contributing to a skills gap in the very skills we need most. Young people everywhere are ambitious for their futures, and employers want workers with technology and digital skills. The Government has consistently failed to ensure school-leavers have these.

Why the Government is failing

The Government is distracted by scandals and sleaze of its own making, which as well as impacting confidence are a major barrier to the job of governing. More fundamentally, on science they seem intent on making the same ideological mistakes as the Thatcher government. That treated scientists as individual entrepreneurs rather than part of communities, and science as a magical springing-up of knowledge rather than part of an active, deliberate search for understanding.

It has compounded this by hampering the international, collaborative links that science relies upon. We still have no answer to what will happen with future involvement in Horizon, working with scientists and individuals in the EU. Last year, the Government also wilfully sabotaged collaborative research across the world by its disastrous cut to Official Development Assistance (ODA).

It is trying to cover these deeper problems with spin. In the Levelling Up paper, for example, they have taken the language (but not the insights) of the economist Marianna Mazzucato, by setting out a series of 'missions' which include R&D. The problem here is that these missions, like the missions in the ARIA programme, are both unambitious and entirely dependent on the current Minister's imagination – the Levelling Up Bill makes clear they can be changed on a Ministerial whim. George Freeman may believe in science but his Government is ideologically opposed to active government, specifically the very idea that a Government can make strategic interventions for the public good. Such interventions are what we need to produce the ideal ecosystem for science in the UK.

This is why innovation is at the heart of Labour's industrial strategy. R&D spending is currently just 1.7% of GDP, the lowest in the G7. The Government has committed to reaching 2.4% which is about average. Labour believes Britain is a science leader and, what is more, our future depends on being an innovation nation. That is why we have committed to raising R&D spend to 3% of GDP. However, delivering an innovation nation takes more than money, it requires a mindset change, whereby science becomes part of our national DNA – for everyone, not just the lucky few – and becomes integral to the public good.

This is a no-brainer for our economy – the Campaign for Science and Engineering found that for every £1 invested by the Government on research and development, we get back 20p-30p each and every year. Research from Kings College London and Brunel University also showed that for every £1 invested in medical research, we get back 25p to the economy each and every year[1]. Labour wants to see investment in science across the whole of the UK, so that every region and nation can thrive.

We also need to tackle the shortfall of STEM workers and Labour would help encourage women and those from under-represented backgrounds into STEM. Widening access to opportunities in science is not just the right thing to do for the individuals; tapping into this talent will strengthen the sector by diversifying decision-making.

Key to becoming a science superpower will be developing the UK's capacity to turn ideas and invention into commercial usage. The passage of the National Security and Investments Bill showed the Government slowly starting to take action on an issue we have been calling for: protecting key industries and assets from foreign hostile takeovers. It also showed the Government's limited thinking: the Bill contains little in the way of protections for startups and no mechanism for supporting a business that is prohibited from being sold off.

Indeed, the Government's flagship programme for innovation, ARIA, shows that the Government is not doing anywhere near enough to help Britain become a science superpower. ARIA should have been an opportunity to direct science and research towards key missions, like preventing future pandemics and tackling climate change, but instead it will have no mission and no proper oversight.

Labour and the Government are agreed on the need for greater support for UK science, but only Labour has the vision to make that a reality more than a soundbite. Labour wants to make the UK into an innovation nation, with science and research at the heart of tackling key societal challenges such as climate change, an ageing population and emerging technologies. Doing so will allow us to tackle regional inequality and provide good quality jobs for people from all backgrounds across the country. We cannot afford not to. □

DOI: 10.53289/SGHD9481

1. www.kcl.ac.uk/news/every-2-invested-in-medical-research-delivers-a-return-equivalent-to-25p-every-year-forever-2

CONTEXT

In June 2021, the Prime Minister announced the creation of a new National Science and Technology Council (NSTC), to "provide strategic direction on the use of science and technology as the tools to tackle great societal challenges, level up across the country and boost prosperity around the world". He also announced the creation of a new Office for Science and Technology Strategy (OSTS), to be based in the Cabinet Office, which would "drive forward the strategy of Whitehall's science and technology priorities from the centre". The OSTS would be headed up by a National Technology Adviser and Sir Patrick Vallance was appointed to that role.

On 26 January 2022, The Foundation for Science and Technology held an event to discuss the establishment of the NSTC and OSTS, their emerging priorities, and how they needed to work with other structures within the UK's science, technology and innovation ecosystem and with industry. The speakers at the event were Sir Patrick Vallance (National Technology Adviser), Professor Dame Ottoline Leyser (Chief Executive of UKRI), Naomi Weir (Programme Director – Innovation at the CBI) and Professor James Wilsdon (University of Sheffield). A video recording, presentation slides and speaker audio from the event are available on the FST website: **www.foundation.org.uk/Events/2022/How-can-the-National-Science-and-Technology-Counci**

Creating strategic advantage in science and innovation

Patrick Vallance

SUMMARY

- Science and technology capabilities can confer strategic advantage on a country
- The Vaccines Taskforce shows one way in which this can be used
- Strategic advantage in any area will involve a number of Government Departments
- Success will depend on involving the private sector
- The NSTC must focus on long-term opportunities for the UK.

Speaking to the Foundation four years ago about the Government's target for 2.4% of GDP to be devoted to R&D, I noted that the UK is extraordinarily good at fundamental science and scores extremely well by any metric. It was also improving its record in encouraging startups and creating successful new companies. However, there was still a big gap in the ability to scale those companies and there remained the challenge of improving take-up of innovation in larger companies. Around the world no other countries had managed to increase R&D spend to the same degree as that planned for the UK without a major contribution from the private sector.

Two and a half years ago, just before the pandemic, the Science Capability Review was published. This focussed on Government science and engineering, specifically its ability to use science to inform policy and its part in delivery. A number of recommendations were made including the need to increase the number of scientists and engineers in Government, increase the ability of policy users in Government to use science, increase the funding in certain Departments and enhance the ability of Departments to be good procurers of innovation.

Then, in March 2021, the Government published the *Integrated Review of Security, Defence, Development and Foreign Policy*, an attempt to lay out the position of Britain in the world. The subtitle was 'Global Britain in a competitive age'. Science and technology ran through the document.

From that document came the notion of 'strategic advantage'. The number of countries that now employ science and technology strategically is much greater than ever before, and they are very alive to the fact that this capability can give them an advantage. If a country decides that it wants an end-to-end capability in an area, from research through to procurement, utilisation, societal benefit, wealth creation, etc, we can label that an 'own' strategy. If, on the other hand, it wants to major in some parts but not others, it would need to collaborate with others. Finally, if it needs to access an area of technology but not follow the first two routes, then it would need some policy around access, whether an investment policy, a relationship policy or something

Sir Patrick Vallance Kt KCB FRS FMedSci FRCP holds the roles of Government Chief Scientific Adviser (GCSA), National Technology Adviser (NTA) and Head of the Government Science and Engineering (GSE) profession. Prior to this, he was a clinical academic at UCL and joined GlaxoSmithKline in 2006, where he was President, R&D, from 2012 until 2017.

The point is that there was a mission to create a legacy, to leave us with a vaccine infrastructure which will be useful for the future.

else. So the 'own/collaborate/access' framework provides a way to think about science and technology advantage. It is a hierarchy that allows prioritisation – "own" can also include collaborate and access, but a decision simply to access would not invest beyond that.

The aim for any country, then, is to create a platform that is impactful as well as relevant and beneficial for society.

Vaccines

A recent UK example of the 'own' model is vaccines. As early as January 2020, it was obvious that vaccines could be an important way through what was a looming pandemic. Yet a fully enabled vaccines industry in the UK had largely disappeared. This was not a conscious decision, more benign neglect. Nobody had thought out the requirements for end-to-end enabled capability or what the UK really needed.

So with vaccines the Government put in place the Vaccines Taskforce, which brought the UK to a position of early development of vaccines and rapid deployment. I identified seven key points as to why the taskforce model worked.

First, content experts were brought in very quickly, including from industry. Second, this was an 'at risk' investment: a portfolio was needed where it was accepted that some elements would fail – but hopefully some would succeed. That 'at risk' mindset was crucial, as it will be in many other areas in the future.

How would the National Audit Office or the Parliamentary Accounts Committee have viewed this had the project been largely unsuccessful? It is certainly something to think about for the future, but the fact that this was 'at risk' was important. Then, this was not just about procurement. R&D, innovation, manufacturing and procurement were all brought together in order to ensure we would be able to procure what was needed.

Fourth, there was a very clear objective: get an effective vaccine out by the end of the year. The fifth factor was single point accountability. Kate Bingham was appointed in May with accountability to deliver against the objective – and the authority to get on and do it. Sixth, the private sector was integral to this, it was not just a civil service or academic activity. The private sector was involved at every stage, including providing specific expertise.

The final point is that there was a mission to create a legacy, to leave us with a vaccine infrastructure which will be useful for the future.

Those seven points will be applicable to other areas as well – although not all. These initiatives involve a number of things that are not normally regarded as part of the S&T landscape: deployment, supply chains, procurement skills, international collaborations, infrastructure, regulations and finance. Yet they are critically important if Government is to be successful.

Assessment

Government needs to determine whether particular technology areas require end-to-end capability. This would have to be long term, across more than one Government cycle. Few of the areas under consideration for this approach will sit neatly with just one Department; they are very likely to cross several. The factors that will make companies invest include not just the skills base, but also other things, like transport, housing, cultural environment, the things that matter to their staff. So these initiatives will have to be cross-Departmental.

The determinations must also be informed by evidence. To provide a solid evidence base, an emerging-tech horizon-scanning function has recently been set up, as well as a technology and science insights function to try to objectively assess the relative strength of the UK and competitors. The term 'world-leading' is often used in a science context but what does that actually mean? Well, the aim here is to provide an objective, independent view, to aid those actually making the decisions. We should be as aware of our gaps as we may be of our strengths.

NSTC

The idea behind the National Science and Technology Council (NSTC) is that, when a Prime Minister comes into office, he or she should concern themselves with three things on Day One: national security, the economy, and now science and technology. All of these are fundamental to the future of the country. The Council, therefore, should be a ministerial committee, chaired by the Prime Minister, that takes a rounded long-term view over the funding of the things that really matter.

The foundations of science and technology in this country are: the research science base, which is strong; the work of UKRI (and hopefully ARIA will have a place here too); and the engineering base. Yet there are many other things that need to come into play. If there is to be a truly integrated strategy and if businesses are going to invest,


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Health and life sciences is one key area targeted by the NSTC, with a focus on scaling up start-up companies.

there will have to be a public commitment to long-term backing of programmes, including the public procurement of innovation.

Four areas that the NSTC has agreed to work on initially are: first, the sustainable environment; then, health and the life sciences; third, national security, defence and space; and then fourth is digital and the data-driven economy. Those are broad areas which the UK ought to be good at and should be able to turn into both companies and sustainable benefits for society.

The work of the NTSC

What sort of decisions might this committee make? First, there are general enabling decisions. Should the regulatory framework be re-drawn in such a way as to encourage innovation across all these sectors? What infrastructure is essential for programmes to work (high performance computing, for example, underpins a great deal of activity)? What skills are needed – from school through to the workplace – that enable a high-tech industry to work?

The failure to scale-up companies is a critical brake on UK success. The USA has a relative three-fold greater investment in startup companies than the UK. In scaling-up, the figure is nearer 10- fold. So, this is an essential issue to focus on. A mission-orientated approach (such as occurred with the Vaccines Taskforce) could be used, for example to pull through technologies for net zero areas. International relationships matter, particularly the ability to collaborate and interact, not just between scientists, but across the whole system so that the science can be taken all the way through to utilisation.

This Committee will also need to take decisions on specific technologies, where the Government would want to take a long-term view. Other countries have done this: Israel has focussed on making sure Government procurement of innovation acts as a significant pull factor. Singapore decided to move into deep-tech and away from biotech, backing that decision with an investment fund for other parts of the overall process.

Fundamentally, it all comes down to choices about where the country needs to be fully enabled. In some areas where there is great science, it may not be feasible or desirable to take it all the way through: we cannot do everything. In others, we may need to put more funding into everything from basic research through to procurement.

The NSTC cannot concern itself with directing basic science which must be led by curiosity-driven science and supported broadly. Yet it must focus on taking decisions about those areas where there are long-term opportunities which need all parts of the system to be joined up across different Government Departments if they are to flourish. Delivery will be crucially important. ❐

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Delivering across a range of sectors and disciplines

Ottoline Leyser

Professor Dame Ottoline Leyser is the Chief Executive of UK Research and Innovation (UKRI) and Regius Professor of Botany at the University of Cambridge. Prior to this, she was Director of the Sainsbury Laboratory, University of Cambridge. 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. In 2017 she was appointed DBE for services to plant science, science in society and equality and diversity in science.

SUMMARY

- The breadth, depth and quality of the UK's research and innovation is exceptional
- UKRI will be a critical element in delivering strategic advantage
- UKRI is the largest public sector funder of research and innovation in the UK
- Fully realising R&I opportunities requires oversight of a range of factors in the wider economy
- The creation of OSTS and NSTC provides a high-level strategic view.

The UK has an extraordinary track record as a nation of research and innovation, across many disciplines. It is not common to have such breadth, depth and quality. We have an opportunity to use this extraordinary national strength to deliver a more sustainable and inclusive knowledge economy, one which will feed not only the wider economy, but also our public services.

The Integrated Review, and the work of the science function across Government, remind us that we will never have the amounts of money available to China or the USA. The UK is a comparatively small country, but with a very broad set of expertise and skills. Building global strategic advantage needs an holistic consideration of our resources, investing them carefully in order to capture the extraordinary bottom-up benefits of the creativity and diversity in the system.

The UK is a comparatively small country, but with a very broad set of expertise and skills. Building global strategic advantage needs an holistic consideration of our resources.

National asset

Very few countries have organisations like UK Research & Innovation (UKRI). It will be a crucial national asset in delivering on this ambition, precisely because it connects across disciplines and across sectors. It connects the extraordinary crucible of bottom-up discovery science with that of innovators across the system, joining the two to deliver value of all kinds into the economy and into our public services.

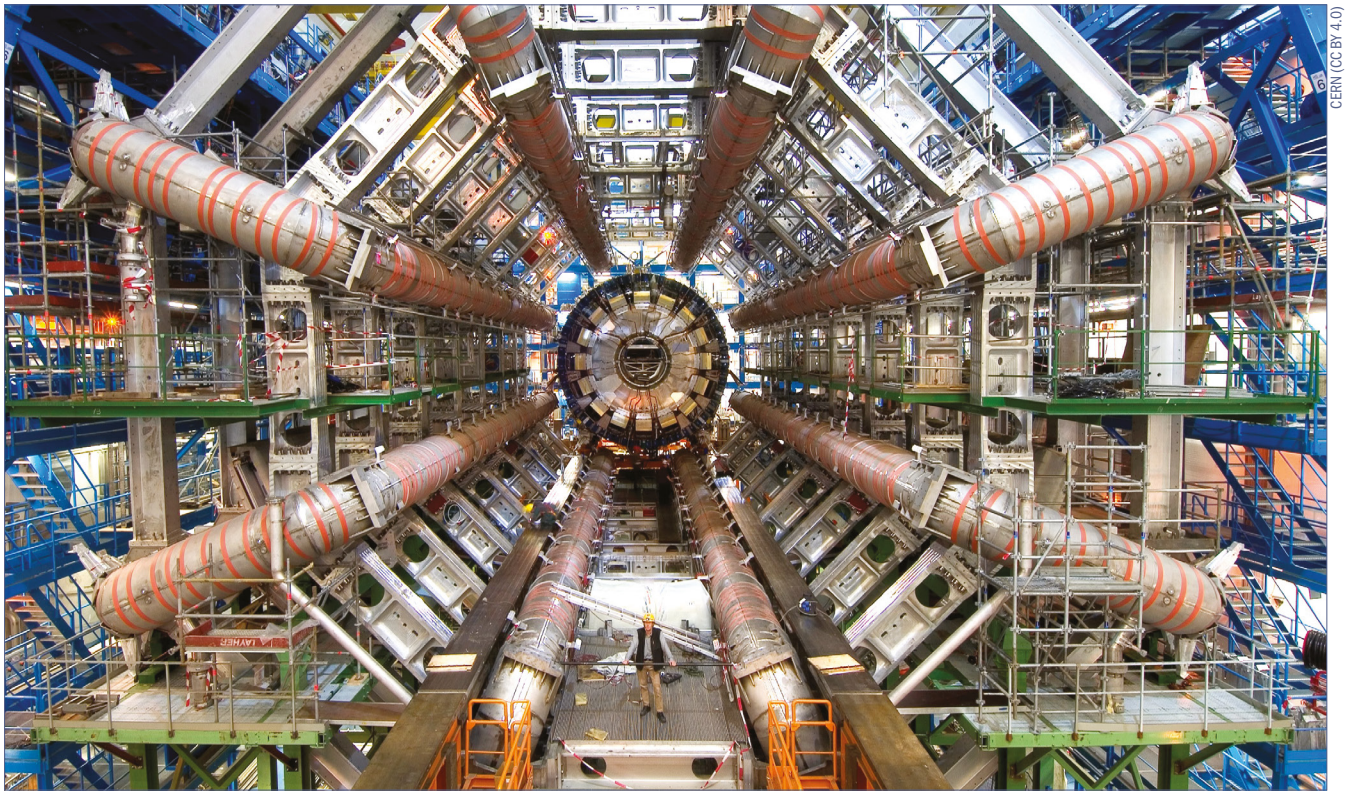
UKRI is the largest public sector funder of research and innovation in the UK. It includes Innovate UK, the UK's Innovation Agency, and Research England which works very closely with the equivalent bodies in the devolved nations to support our extraordinary university system. Then there are the seven disciplinary Research Councils that fund a full gamut of research, from the completely blue skies open-ended kind through to more applied and business-driven collaborations. Having all of those 'under one roof' allows UKRI to think much more intelligently and in a coordinated way about the overall investment portfolio.

UKRI is a public body, accountable to Government. While constituting a large proportion of the UK's R&D investment, it is part of a much broader system of academia, business, the public sector, third sector and international partners.

UKRI has around £8 billion a year to invest. That is divided across a range of core national capabilities. Just over 10% goes into PhDs, studentships and fellowships, i.e. on specific investment in people, with many more researchers and innovators funded through project grants. Yet the research and innovation workforce is much broader than that: not just the researchers and innovators but all the very diverse technical and administrative roles too, which are essential for high quality research and innovation.

Fully-open response-mode project grant funding accounts for only about 12% of the UKRI budget, but it is a critical part of what UKRI does. This is the fuel for later projects and programmes. A further 7% is targeted on opportunities that individual Research Councils see as really important to drive up investment and interest in particular areas. Overall, then, approximately 20% of the UKRI budget goes into response-mode funding of the research base, and this is crucial also for attracting world-class talent: people can see that in the UK they can attract the funding to drive the programmes that excite them.

About 20% of UKRI funding goes into English universities in block grants, giving them the flexibility and strategic opportunity to fine-tune their research portfolios in the way that they want. This huge sum of money, that goes out in a completely unhypothecated way, is where a great deal



of the system's agility comes from. It is that open funding that allows institutions to pivot and change direction if they need to.

About 12% of the UKRI budget is allocated to infrastructure of various sorts, including big international projects like CERN, but also key facilities in the UK and the day-to-day equipment that goes into labs. A further 10% goes into research institutes and national laboratories.

Then there is funding in the innovation area. That includes the Catapult centres that bridge the gap between innovative businesses on the one hand, and Higher Education Institutions and the wider research base on the other. Response-mode innovation funding operates through Innovate UK to support mainly SMEs in driving forward their innovation projects. More recently, the Industrial Strategy Challenge Fund, challenge-led funding driven by key industrial challenges that need solving, brings together interdisciplinary teams on, for example, battery technology.

In addition, UKRI provides funding that specifically targets international activity. That accounts for about 6% of the total, although many UKRI programmes have an international element. Finally, around 5% of UKRI funding is currently targeted on COVID programmes.

A diverse range of activities

So, as a single organisation, UKRI has the opportunity to manage its portfolio across all these elements in order to deliver on a whole variety of goals. It can coordinate investment across the system, both to deliver key priorities and to balance current priorities against opportunities in the future. Through its knowledge of what is happening across the system, its analytical teams can understand what is happening domestically and use that information to tune investments dynamically and connect the different elements of the system so that people and ideas move freely through it.

I welcome the establishment of the Office for Science and Technology Strategy (OSTS) and the National Science and Technology Council (NSTC) precisely as a higher-order umbrella that allows us to understand and work within a much broader set of activities that are essential to allow us to capture all the benefits achievable.

Activities in the research and innovation base create opportunities. Realising them for the benefit of the economy and public services is really important but requires oversight of a range of other items like the infrastructure, the regulatory environment, and so on.

This is difficult; people prefer linear cause-and-effect, but that is not how the system works. Nationally, we need the intellectual infrastructure to allow us to navigate this system to deliver for the UK. I believe the combination of UKRI, the cross-Government distribution of R&D budgets, together with the OSTS and NSTC give us the capability to get this right, as a fully-wired system where all the parts work together. □

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Activities in the research and innovation base create opportunities. Realising them for the benefit of the economy and public services is really important but requires oversight.

The UK must be more ambitious

Naomi Weir

Naomi Weir is Programme Director of Innovation at the Confederation of British Industry (CBI), the UK business organisation. She leads their work to make the UK a great place for businesses to innovate – whether that is nurturing a culture of entrepreneurship, adopting tried and tested technologies or making breakthrough developments at the leading edge. She began her career in financial services before moving into policy, working on policy areas from R&D and entrepreneurship to skills, immigration and diversity in STEM.

SUMMARY

- The UK needs to be much more ambitious about growth
- Policies should focus on where we want to be, rather than where we are now
- Business needs to invest more and engage more with innovation
- Policies and programmes should have clear, time-bound outcomes
- If we are in a global race, then pace is an important factor which needs more attention.

To get the high-investment, high-productivity economy that we desire, while overcoming the headwinds the country is facing, be they shortages, energy prices and inflation, etc, we need to become much more ambitious about growth. The National Science and Technology Council (NSTC) and the Office of Science and Technology Strategy (OSTS) can have a really important role in delivering that focus.

The UK currently has a medium-term growth forecast of around 1.6% a year. Too often, the actions that are needed to drive really ambitious growth are put on the 'too difficult' pile. Instead of long-term ambitious plans, policies and investment levels are quite shortsighted, targeting quick returns over a one-to-two year period. Being stuck in a short-term, low-ambition cycle has real consequences, not least for innovation and R&D.

To turn this around we need that long-term direction, combined with ambitious policies that aim for higher growth. These should be policies that start not from where we are, but where we need to get to, ensuring the forward planning and upfront investment are in place.

What are we good at?

First, we need to identify our own strengths. What is the UK famous for? Importantly, what do our competitors say the UK is good at? What do people on the street and young people in our schools system think the UK is great at?

The persistent narrative is that the UK is good at research and not so good at innovation. Yet at the same time, in 2020 there was a new unicorn every 13 days in the UK. There is real progress and momentum. So, the general perception of the UK's competitive strengths, both at home and internationally, does not properly reflect the current situation, let alone where – with some coordination – we could get to. That contributes to under-use of the UK's capabilities in pursuing national strategic goals. It also contributes to under-investment, with business not seeing the UK as the best place to locate, while investors do not expect to find the companies or the ideas they need here. It also affects public investment. A collective effort is required to make sure investment from public, private and third sectors reaches our research and innovation base.

The current perception of an under-achieving UK can also lead to under-participation, where individuals do not see the UK as an exciting place to work or train.

The current perception of an under-achieving UK can also lead to under-participation, where individuals do not see the UK as an exciting place to work or train. Skills gaps are consequently particularly acute at the moment in a number of areas, and there are also diversity challenges.

Under-participation by businesses in innovation is also evident. If we are going to achieve our ambitions to grow the intensity of R&D in the UK, we need to grow investment from existing businesses and, in addition, more businesses must get involved in innovation in the first place. That ranges from adopting tried and tested technologies right through to being at the cutting edge. Challenging the current erroneous perception of the UK, and being clear where the UK can compete and win, will really help address that gap.

We need to tell the UK innovation story consistently, both at home and beyond. That means being clear on the UK's real strengths (what we ought to be known for today) and real clarity about what we are aiming to achieve, so that people can join forces towards those ends.

We need clear, time-bound outcomes. There are parallels with the work of the National Infrastructure Commission. It has a different set-up but is tasked with strategy and monitoring. Business really values the rigour of that process, as well as its collaborative style, both informing and galvanising action. The establishment of the OSTS and NSTC promises that kind of rigorous, evidence-based approach, starting with a proper

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The offshore wind market is an example of bold strategic action by the UK Government.

needs assessment, and a baseline assessment of where we are now. From there it will be possible to build an assessment of future need. What different capabilities or capacity are required, what are the goals and aspirations – what is actually needed to get from where we are now to where we need to be?

This may seem very basic, but in reality it is exceptionally complex and difficult, not just because of the scale of the challenge, but also because of ingrained short-termism and the inevitable political headwinds. The new structure also has a direct link into key decision-makers. Once there is clarity on where we can compete, a further sign of success will be if that analysis is followed up with action.

Risk evaluation

Setting our sights on growth, will we take the big bold bets that are needed to get there? The creation of this new structure is a recognition that a re-evaluation of risk is necessary, i.e. including opportunity-cost in the mix. The country needs to be much more purposeful in aligning capabilities and pushing collective leadership in the right direction. The 5G roll-out is a good example of where we missed the boat initially and are now playing catch-up. Had we got this right, we could be in a very different position today.

Offshore wind, on the other hand, is a tale of two halves. Much of the technology is not British and could have been, yet the offshore wind market based on Contracts for Difference is a great example of strategic bold action, with the UK Government using its strategic levers to pull through.

Looking ahead, this new NSTC/OSTS structure can help the UK move from being on the backfoot to running at the front of the pack and setting the rules of the game in those areas which are really important for us. To create those leading positions, the country will need to make use of the outputs of scientific and technological advances. One of the signs that this new approach has been successful will be if we are making the most of these technologies – in Government, in business and in society at large.

This kind of shift requires a recalculation of risk, particularly in terms of Government procurement where risk aversion is a big disincentive to the procurement of innovation. Can we expand the factors so that opportunity cost is considered in the calculation of risk? For example, can we get to a point where not taking the risk to procure innovation in areas where the UK is looking to build strategic advantage is going to be seen as a failure? That would be a huge cultural change but perhaps a sign of success.

The lack of collaboration between public and private sectors is certainly something that must change. Another aspect is speed. There is much discussion of ideas and markets. Yet rarely is the question asked: "How quickly can we do it?" We talk about a global race, after all. There could be more reflection on how to move at pace in the chosen direction of travel. □

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Can we get to a point where not taking the risk to procure innovation in areas where the UK is looking to build strategic advantage is seen as a failure?

Creating a balance between priorities

James Wilsdon

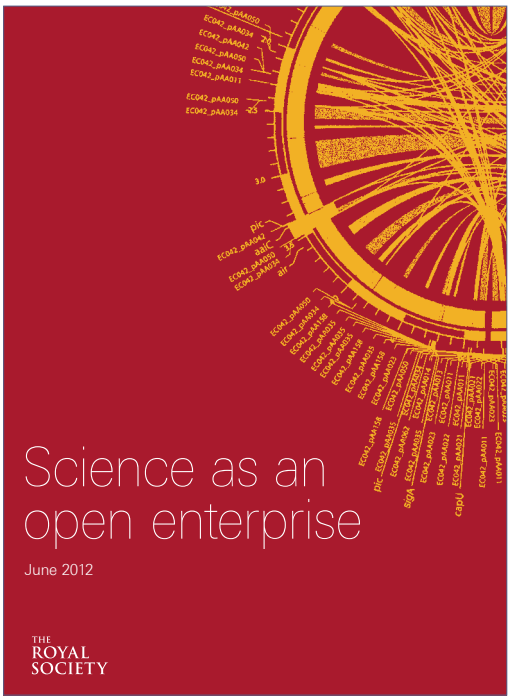
Professor James Wilsdon FAcSS is Digital Science Professor of Research Policy at the University of Sheffield and Director of the Research on Research Institute (RoRI) - an international consortium of research funders, academics and technologists with a mission to accelerate transformational and translational research on research systems, cultures and decision-making. RoRI's consortium now includes 20 research funders from 15 countries, who between them invest over US$ 23bn each year in research and innovation.

A mismatch exists between the secrecy of defence research and the more open world of academia. How should those two cultures mix and engage?

The addition of the OSTS and NSTC to the UK's science and technology system is a familiar dynamic in creating strong central Government structures, and then moving responsibilities elsewhere. Indeed, there are strong echoes of debates around the Rothschild report more than 50 years ago now. There is a recurrent question about Government oversight of the elements of the R&D system which are closely aligned to Government priorities.

The spending review last November gave a palpable uplift to the different parts of the system. It is good to accompany that with clearer, stronger structures to shape both the investment itself and the policy behind it. So for those on the outside of Government, a bit more clarity would be helpful in understanding the relationship between OSTS, UKRI, the minister in BEIS, as well as the existing structures that remain such as the Council for Science and Technology (CST). These latest additions have made understanding the UK system that little bit more complicated.

Over the past few years, there seems to have been more emphasis on tinkering with structures and institutions and not enough on outcomes. It would be welcome to have a period of stability to allow those structures to bed down. It is still not entirely clear how these different responsibilities will integrate once they are all up and running and working at full capacity. Some 18 months ago, the R&D Roadmap process was initiated, an attempt to pull the different strands together in a more coherent strategy that people could read and digest and understand. Yet, it was a process that began but never completed. Perhaps a combination of UKRI's new strategy with the efforts of OSTS and others, can produce that clear sense of how they will also function together over the next five years. While none of us is looking for a Chinese-style Five Year Plan, there is a need for more visible coordination.



SUMMARY

- Greater clarity is needed about how different parts of the Science, Technology and Innovation spheres interact with each other
- A balance needs to be struck between central coordination of research and a more distributed approach
- The pendulum seems to be swinging from collaboration to competition
- These debates are not new, they were being discussed when the Rothschild report was published half a century ago
- The tension between different priorities in research will continue.

Distributed intelligence

Linked to that is a debate which is not new (it was discussed when Rothschild was published) about the balance between central coordination of ST&I policy and a more 'distributed collective intelligence' across the system. There has been much interesting thinking in recent years about distributed intelligence through systems. Given the enormous body of hyper-intelligent people working in the R&D system, we should consider investing seriously in creating the mechanisms and infrastructure to tap into and draw on these more dispersed, diffuse modes of expertise that run through the system.

SHUTTERSTOCK/ HELLORUBY

In any discussion of relationships with others such as China and the EU, the UK must take into account a range of different security interests when considering research openness and collaboration.

There is a traditional tension in research policy between the soft and hard power of science and technology, so between the benefits that flow from international collaboration compared with a hard-edged view of our competitive position and strategic advantage. The Integrated Review could be seen as shifting the pendulum towards a more hawkish view of Britain's place in the world, with science and technology securing and protecting that place. Notwithstanding the references to collaboration, more political attention is being given to the competitive side. This can be seen in the discussion of our relationship with China and the persistent uncertainty about Horizon Europe. Over the past decade, there has been a policy emphasis tilted towards science-diplomacy while now there is a move to a more competitive framework.

Speaking at a recent OECD event, Tarun Chhabra, Senior Director for Technology and National Security on the US National Security Council, noted that he saw the OSTS as his direct counterpart in the UK. In the same speech, he talked about a push that the Biden administration is making on what he called 'democracy affirming technologies'. He argues that the US can draw on its strengths in global science technology networks, as both a collaborator as well as a competitor, to advance technologies that in some way underpin democracy in the Western world. That is one view of what strategic advantage constitutes in the world of 2022.

Culture clash

The Royal Society published a report entitled *Science as an Open Enterprise* that explored the notion of intelligent openness and strategic secrecy. Now, OSTS has to consider a range of different interests including defence, security, etc. The need for secrecy is perfectly understandable in this part of the R&D system. However, that part does sit somewhat removed from the world of many professionals inhabiting universities and elsewhere. How should those two cultures mix and engage?

The balance between soft and hard power, between open and closed, between competition and collaboration is at the absolute heart of the debate on science policy and research. It will continue to be so. □

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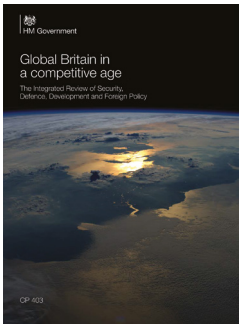
There is a tension in research policy between the soft and hard power of science and technology.

The debate

After the formal presentations, the speakers joined a panel to answer questions from the audience on a range of topics, including: system complexity; dual-purpose technologies; fundamental science; and the role of the private sector.



How do the NSTC and OSTS fit into or affect the current structures? While the addition of new bodies carries the risk of making the RD&I system even more complex – which should be avoided if at all possible – the creation of the NSTC is concerned with the coordination of the existing elements, such as joining up all Government Departmental scientific advisers. There was concern that the advisory and policy-creating functions should be kept distinct and that the two roles of Government Chief Scientific Adviser and National Technology Adviser should be held separately in future.

Organisations like UKRI and the OSTS both help to connect disciplines and sectors, including charitable funders, that would otherwise risk becoming siloed. A survey of businesses found that a key element in convincing them to invest more in innovation is the support available to help them navigate the system, so further complexity could discourage further business investment. There is a clear tension in the commercialisation of activities which also have applications in national security. While some elements need to be confidential, there appears to be little advantage in maintaining high levels of secrecy throughout the entire science and technology journey. The NSTC should be involved in deciding how to shape safe deployment of dual-use technologies that serve interests beyond the purely economic, while decisions on matters of national security should remain outside of its remit.

It is also important to maintain a strong interface between the research base and the private sector business community in order to maximise the benefits of dual-use technologies. During the pandemic, businesses engaged with emerging technologies to help facilitate deployment at pace.

Encouraging a diversity of activity and ideas, by including private and third sectors, should benefit the entire community. It is essential that funding for fundamental science should be protected and maintained separately from directed science and challenge-led funding. In order to achieve the 2.4% increase in R&D funding, private-sector investment will be imperative and so science policy must facilitate and promote business involvement in R&D.

Can the new structures introduce new and diverse voices into the wider RD&I and S&T communities? A 'collective intelligence gathering' is required to seek out those who do not necessarily identify as innovators. The national strategy should aim to create an inclusive innovation economy where everyone can feel involved. For the wider public, a new narrative is required where instead of science being something that is 'done to you', it is done 'by you or with you'. ❐

FURTHER INFORMATION

Global Britain in a Competitive Age, the Integrated Review of Security, Defence, Development and Foreign Policy
www.gov.uk/government/collections/the-integrated-review-2021

Launch of National Science and Technology Council (Government announcement June 2021)
www.gov.uk/government/news/prime-minister-sets-out-plans-to-realise-and-maximise-the-opportunities-of-scientific-and-technological-breakthroughs

Office for Science and Technology Strategy
www.gov.uk/government/groups/office-for-science-and-technology-strategy

Royal Society (2012) Science as an open enterprise
https://royalsociety.org/topics-policy/projects/science-public-enterprise/report

Wellcome Trust (2019) A blueprint for the oversight of emerging science and technologies
https://wellcome.org/reports/blueprint-oversight-emerging-science-and-technologies

CONTEXT

In November 2021, the COP26 climate change conference was held in Glasgow, bringing the leaders of the world together in the most important COP meeting since Paris in 2015. Under the UK Presidency of the COP, this meeting was seen critical in seeking global agreement to take actions to limit emissions and keep the target of 1.5˚C of warming within reach.

On 1 December 2021, the Foundation for Science and Technology brought together four leading experts on the issue: Professor Sir Ian Boyd (Professor of Biology at the University of St Andrews), Baroness Young of Old Scone (House of Lords), Professor Sir Charles Godfray (Director, Oxford Martin School, University of Oxford) and Professor Sir Dieter Helm (Professor of Economic Policy, University of Oxford). Video, audio and presentation slides are available on the FST website at **www.foundation.org.uk/Events/2021/COP26-Where-do-we-go-from-here**

This event was dedicated to the memory of the Earl of Selborne, a previous Chairman of the Foundation, who passed away in February 2021. An obituary appeared in *FST Journal*, Volume 22 Issue 10.

Achieving our goals will require a major cultural shift

Ian Boyd

SUMMARY

- The policy framework needs to encourage individuals and institutions to act
- An effective strategy needs to tackle all the indirect emissions that occur in a company's value chain
- It will not be sufficient to cut carbon: institutions will have to absorb it as well
- Policy innovation is just as important as technology innovation
- Sustainability is more than just net-zero carbon.

At the University of St Andrews, I am responsible for changing the business model to become a net zero institution. I also co-chair the Scottish Environment Council with Nicola Sturgeon. Looking through those two lenses enables a view over institutions across the country, everything from local authorities to SMEs and large corporates, as well as universities: in fact, all those institutions that collectively have to achieve net zero if the country is going to get there.

In my experience so far, there is not much difference between the challenges at an institutional scale and those at national scale, although the results are slightly different.

What do institutions need to do? Similarly, what do national governments need to do? And how do those two programmes interact? Well, governments will need to create a policy landscape to allow not just institutions, but individual citizens as well, to make the choices required to get us to net zero. Institutions will have to plan within that context how they will deliver that outcome. There are a few factors to take into account. The journey to net zero is a long one. The University of St Andrews, for example, has decided to achieve this by 2035. And it is going to be really hard work. It has also won a sustainable institution award, but not for the progress it has made, rather because it is facing up to the realities of what this means. A lot of the talk about net zero is just greenwash.

There needs to be a change in the culture from top to bottom of the institution. The idea that net zero can be achieved by tackling scope one (direct emissions from owned or controlled sources) and scope two (indirect emissions from the generation of purchased electricity, steam, heating and cooling) emissions is a complete fiction. If everybody did that, then we would never make realistic progress.

We need to include scope three emissions, all those other indirect emissions that occur in a company's value chain. That is an ethical requirement. Within a university context, the students absolutely insist on it. Therefore, the business model needs to change.

What does that mean in reality? For a university, it means that by the target date we will be doing things very, very differently. In addition, it will not be sufficient just to cut carbon out of the inventory, it will have to be absorbed as well. A university like St Andrew's has to absorb about 40,000 tonnes of carbon by 2035, if it wants to get

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A university like St Andrew's must absorb about 40,000 tonnes of carbon by 2035, if it wants to meet its net-zero target.

REMI MATHIS (CC BY 3.0)

to net zero: that is the size of the challenge.

Statutory reporting is ineffective, providing no real incentive to the universities at all. The regulatory playing field is almost non-existent. Institutions like the University of St Andrews are not getting the help they need from Government, i.e. policy help. It is in the national context where that policy help can be implemented.

However, I believe COP26 asked the wrong question: it asked how to reduce greenhouse gas concentrations in the atmosphere. We will never get these down unless consumption is reduced: it is a mass balance problem. The more we consume, the more pollution we create. And part of that pollution consists of greenhouse gases.

The flow of natural resources into the economy (domestic extraction) is accelerating. At the same time, material productivity is declining overall and there is increasing evidence of resource exhaustion. In effect, humanity is paying more to run faster and go backwards.

In Scotland (and it is much the same for the UK and Europe) each person consumes on average about 18 tonnes of raw materials a year. That must reduce to below eight tonnes in order to be sustainable. Now that creates a policy problem.

A recent update to the *Limits to Growth* scenarios that were run in the early 1970s produced some new, plausible scenarios for the globe. They were run on the data that we currently have, including population change, but also resources and rapidly rising pollution. In the BAU scenario, the update shows industrial output falling rapidly over the coming decades. This can, I think, can be looked upon as a reasonable worst case scenario – which is what those in Government should be planning for. Are we doing so? Absolutely not.

Logically, innovation and investment in technology might change this, but not enough to resolve the scale of the challenge of this kind of scenario. So, this is not just about greenhouse gases, but about the way humanity manages the resources of the planet, while reducing pollution at the same time.

In the current policy context, there are a wide range of supply-side policies: the focus is on market solutions, deregulation, subsidy (which includes fossil fuel subsidies). There is a relatively small number of demand-side policies, about regulation, fiscal measures and incentivisation. Demand-side policies are hard to implement. Politicians do not like implementing them. This is because it means saying to people: "You may want this, but you can't have it." But that is what is needed. It is not a matter solely of reducing the supply-side policies: some of them are very good. However, they must be balanced on the demand side. We need to internalise the environmental costs.

I personally think the machinery of government needs to change. Until now, we have failed, repeatedly, to step up to this challenge. Policy innovation is just as important as technology innovation, and the latter will not work without the former alongside it. Policies must empower institutions and individuals to achieve the required results in a market-based context.

Finally, sustainability is more than just net-zero carbon. Even if we get to 2050 and achieve net zero, it will not have completely solved the sustainability problem. It will just be there in another form. □

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A great deal more still to do

Barbara Young

SUMMARY

- COP26 recorded a number of significant achievements
- A number of others remain incomplete
- The UK must lead by example
- It is not clear that the UK Treasury has yet grasped the full extent of the challenge
- There must be a just transition to a net-zero world.

COP26 did record a number of achievements. The completion of the Paris Rulebook was important, setting the rules for carbon markets and encouraging people to be more ambitious about their enhanced Nationally Determined Contributions (NDCs) now they know what the rules are. More countries than ever before were involved in the process and have signed up to net zero – even India after a fashion! Coal was included for the first time, albeit in a heavily diluted way. At least it is a start: everyone knows that 1.5˚C cannot be achieved if the world still burns coal.

The side deals were probably more important than the main event. Methane and deforestation were elements in that, although they lack any formal monitoring and reporting mechanisms at present. There were sterling efforts behind the scenes and 133 countries did sign up to the deforestation deal. Here in the UK, we need to set an example by not destroying or damaging remaining fragments of important forest or ancient woodland (there are still over 1,000 areas of ancient woodland under threat in the UK).

The issue of a joint statement by China and the USA was an interesting development. We wait to see what these channels deliver. Some revisions to the process were encouraging, for example businesses tended to be represented by chairmen and chief executives. The commitment to come back next year with enhanced NDCs signals a ratcheting up of ambition, which is welcome. The Glasgow Financial Alliance for Net Zero (GFANS) has now doubled the assets globally under management for tackling the climate crisis.

Of course, there were items that did not come through: the $100 billion per annum funding commitment was not delivered. The compensation for poorer countries and small island states for the impact of our pollution is still unresolved. Nature-based solutions were talked about a great deal but there were few mechanisms proposed for their delivery. Importantly, there is very little linkage between the biodiversity summit (COP15) and the climate change summit (COP26). Yet, it is absolutely axiomatic that 1.5˚C cannot be delivered without restoring our biodiversity.

Adaptation did get some attention. The budget was doubled, although from a very low base. I welcome the agreement for a two-year process to create a global plan for adaptation, but that means it is another two years away. Adaptation will be increasingly important, not just in Bangladesh, the small island states and in the increasingly arid regions, but also here with extreme weather events, fires, droughts, floods, etc. In reality, adaptation will also be about immigration, as the populations of the world seek a living elsewhere when their own territories become increasingly hostile. And this is a pressure we are already experiencing.

Although there was a significant amount of unfinished business at the close, there were a number of important agreements made at COP26. Will they be implemented? Who knows?

The Presidency

There are a number of actions the UK Presidency and the Government could be doing over the coming months. We are the president until COP27 in Sharm el-Sheikh in November 2022. Alok Sharma will need to re-energize the process, make sure the enhanced NDCs come forward, ensure the agreement between China and the USA does have some impact.

He will have to embed processes for the implementation of commitments already made, particularly the side deals, and make sure that we get over the line on the $100 billion annual funding. In the grand scheme of things, this may not be a huge amount of money, but it is a sign to the small island states and the emerging world that some action is being taken by those who caused the historic pollution. Then, of course, the Presidency needs to ensure that the private sector makes good on the promises of funding.

The UK must lead by example. The Government needs to set zero-carbon and biodiversity tests for all policies right across the board. There should be no trade agreements without climate

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SHUTTERSTOCK/ WILLIAM BARTON

The House of Lords Science and Technology Committee found that some Departments, such as Education, were unaware of their potential contribution towards net zero.

change parity being a precondition: if our farmers and businesses are to meet climate change standards, we should not be signing trade agreements with countries that do not. That would be bad for our companies, and bad for the planet.

Each Department needs to evaluate its own contribution to the campaign against climate change. The House of Lords Science and Technology Committee took evidence from a range of them, to find out what their plans were for COP26. I was amazed at what we were told. The Department for Education, for example, clearly had no concept that education could play a role in climate change.

The Government should develop a strategic land-use framework to make sure that we use this scarce resource effectively for carbon sequestration using trees and peat: the right tree in the right place as the Woodland Trust urges, and at a fast pace. The land-use framework is also needed to ensure a transition to lower emissions from food production (especially methane from meat and dairy) and increases in plant-based food as outlined in the National Food Strategy, while still retaining a vibrant and economically-viable farming industry.

Rather than a scattergun of initiatives, we must have a properly sustained action plan for our highest carbon and greenhouse gas emitting areas – energy, building, transport and agriculture – with timescales and funding, as well as transparent pathways that can be monitored. Defra should publish its Environmental Land Management Scheme urgently. Farmers, and the country as a whole, have waited far too long for this to see the light of day. The Net Zero Strategy has significant gaps and needs attention. The Government is also placing too much faith in key technologies. Green hydrogen, for example, is still some way away but is (worryingly) crucial to many of the elements of the Strategy.

Generally speaking, the Government over-focusses on the 'white heat' of technology – on hydrogen and on Carbon Capture Usage and Storage (CCSU), and not enough on fiscal and taxation measures which could reduce the price of climate-friendly technologies while increasing the price of polluting goods and services.

All public sector procurement should include zero-carbon targets. This is a huge lever with which to drive the development of climate-friendly goods and services. The market as a whole will be modified as a result of that amount of spending power. No Government has ever used that lever effectively. The climate crisis means that we must.

The Treasury

I am not sure the Chancellor quite 'gets' climate change. Most of the big changes needed are not about upfront funding but rather fiscal and taxation measures. As yet, there is no climate change commitment from the Treasury. Its analysis, which accompanied the Net Zero Strategy, spoke a great deal about other Government Departments but not about the Treasury's underlying philosophy. The Chancellor must outline an ambitious strategy well beyond modest funding for new technology development and implementation. Setting an example could include halting the massive subsidy to Drax for inappropriate biomass extraction, which is adversely impacting on international biodiversity.

Crucially, the world must ensure that the system delivers a transition that is just. This is not just an ethical point, it is a practical necessity. There are already signs that many individuals, farmers and business people believe that net zero measures have an unacceptable upfront cost, which impacts most severely on business, on the poor, on the vulnerable. If that perception becomes general, we will all fail.

The voice of youth

Finally, we must keep faith with young people. We have seen the power of young people to move mountains. Well, they are going to inherit this mess. If we do not keep faith with the huge power of their young voices, they will not forgive us and humanity will not win through. □

DOI: 10.53289/TGOK8067

Significant steps on a long journey

Charles Godfray

SUMMARY

- Glasgow saw a number of achievements
- The private sector is becoming increasingly engaged in the move to net zero
- Geopolitical issues are slowing progress in key areas
- The difficult issues about changing people's behaviour have not been tackled
- The UK Government needs to develop a land-use framework as a matter of urgency.

There were a number of positive developments at Glasgow: completion of the Paris Rule Book and an increasingly large number of countries committing to Nationally Determined Contributions (NDCs) for example. India's ambition may need to increase over time, but the mere fact that they have set a timeframe – albeit 50 years ahead – is important.

Written into the final communique is the need for a 45% reduction in greenhouse gases by 2030 and a reaffirmation of the 1.5˚C target. There were positive statements on the importance of putting a price on carbon and making carbon border-adjustments. There has been progress in the EU over the past year on that.

There were also negative aspects. Progress on transferring $100 billion annually from the rich to the poor world to help for mitigation and adaptation was glacial. This question of geographic equity is going to be such an important issue at COP27 in Sharm El-Sheikh.

The complex issue of the Loss and Damage Fund was discussed but without much progress. Interestingly, only Scotland and Wallonia have made contributions to the Fund so far!

The alliance that Mark Carney put together of 400 financial institutions is potentially important. Those companies are responsible for $130 trillion of assets under management. If those assets are genuinely aligned to net zero, that will make a difference. There is a real air of change in the private sector about this (though there is still lots of greenwashing about).

The initiatives on forests are welcome. We have, of course, been here before in 2014. Now, though, more countries are involved and there is some real money on the table. Forests are complex and the agreement lacks legal enforceability. Yet there has been enormous progress in the ability to monitor deforestation in real time and 75% of the avoided emissions from forestry occur in just three countries, Brazil, Congo, and Indonesia. So by concentrating on those three countries we can make real progress. It was good to see the UK put in an investment of £500 million towards the protection of forests.

I am concerned by the geopolitical headwinds evident at Glasgow. The Chinese were engaged, but not as much as might have been hoped. The China-US Joint Statement was a positive development but the hope that China would focus on climate change in isolation from all the other things it is concerned about was never going to be realised.

On methane there is a commitment to reduce emissions by 30% by 2030, although it needs to be 45%. Also, China, Russia and India are not among the signatories. Looking closely at the declaration, there is a lot of detail on the technological innovations that could reduce methane emissions from gas pipelines and from livestock. Some of the difficult issues are avoided, though, including diet change which will have to happen. Methane is a powerful but short-lived greenhouse gas and action here will be essential if the world is to remain below the 1.5˚C threshold.

Nature and climate are becoming more closely linked. The UK is committing £40 million for a global centre on biodiversity and climate which is welcome. The issue of food has been outside the main COP process over the years but that seems to be changing. There were a series of announcements from the UK which, while modest, are exciting. £25 million will go to the CGIAR system of international laboratories responsible for the Green Revolution, which have been starved of funds over the past 10 years.

There is also a USA-UAE agricultural innovation mission for climate which has now attracted £4 billion. More research into agriculture is desperately needed, research which seeks not just to increase yields but also to increase sustainability. However, it is relatively easy to make these commitments on

Professor Sir Charles Godfray FRS is Director of the Oxford Martin School at the University of Oxford. He is a population biologist with broad interests in the environmental sciences and has published in fundamental and applied areas of ecology, evolution and epidemiology. He is interested in how the global food system will need to change and adapt to the challenges facing humanity in the 21st century, and in particular in the concept of sustainable intensification, and the relationship between food production, ecosystem services and biodiversity.

There was a series of announcements from the UK which, while modest, were exciting.

Countries are still shying away from some of the hard demand-side issues, such as action on sustainable (and healthy) diets. There is also the politically difficult subject of pervasive and counter-productive subsidies.

the supply side. Countries are still shying away from some of the hard demand-side issues, such as action on sustainable (and healthy) diets. There is also the politically difficult subject of pervasive and counter-productive subsidies. Most people know about the way these are used in the energy sector, but they are almost as common in the food sector and they act against sustainability.

There is one thing the UK Government should do as a matter of urgency. It has made a series of commitments on biodiversity, on net zero and on the rural economy. It is not clear that these all add up. We need to have a land-use framework in order to bring these all together in a coherent way.

Now that we no longer in the EU, we can use the money we put into rural economies in different ways. Several years ago, Defra published a document called *Health and Harmony*: in my view the most interesting document to come out of an environment and farming sector since the last war. This articulated a commitment to net zero and the possibility of completely reformulating the way we support our rural economy to produce a multitude of public and private goods. If we can get that right, it will have a major effect on both climate and biodiversity. □

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A new approach is needed if a net zero world is to be achieved

Sir Dieter Helm, Professor of Economic Policy at the University of Oxford and Fellow in Economics at New College Oxford, also spoke at the meeting.

In his talk, Sir Dieter Helm noted that the world was adding two parts per million annually to the concentration of carbon in the atmosphere. This has been happening for the past 30 years without exception. None of the Conferences of the Parties has so far made a dent in that accumulation.

Even in 2020, despite a steep reduction in emissions due to coronavirus lockdowns, he stressed that the world had still added a further two parts per million. The key statistic, he argued, is the concentration of carbon in the atmosphere, not just territorial carbon emissions. That involves both sequestration, i.e. the way our natural world absorbs carbon, and emissions.

Nationally Determined Contributions (NDCs) of carbon reductions are not, he noted, legally binding. Similar commitments have never been fully met in the past. Even if they were in the future the world would still experience more than two degrees of warming. Climate change is not going to be solved in Glasgow or London. The solutions will primarily be found in places like China, India and sub-Saharan Africa.

Yet China does not intend to stop increasing its emissions of carbon until 2030. It currently accounts for nearly 30% of global emissions. India expects to take half a century to get to net zero. He argued that, given what has happened so far, proponents of this process really need to explain why 'one more heave' is going to work now.

There were some important agreements at COP26 but these are not going to deliver the change required. The funding commitment to developing countries is not being met in full. The deforestation programme is not due to deliver completely for another decade, while the destruction of the Amazon proceeds faster than ever. There was also a coal pledge: yet the USA, China and India are not parties to that. The future cannot be built on such foundations, he argued.

If the UK is serious about reducing emissions and not merely offshoring them, all of our carbon footprint, domestically produced and imported, must be treated on the same basis – it all results in carbon in the atmosphere. The obvious way to do so is through a carbon border adjustment. Then, when a ship arrives at Southampton, the owners can only avoid paying the carbon tax if they have an exemption certificate showing they have paid the carbon price to their own Government.

He insisted there should be greater honesty with the population about the costs of decarbonisation. It is fashionable to say these will not be high: that is nonsense, he said. The costs of replacing household gas boilers with heat pumps are not trivial. That is just the beginning of converting an overwhelmingly fossil fuel economy into a low carbon economy.

But he was convinced that COP26 does not provide a sound foundation for taking things forward. The world is in a very, very serious situation. There are pathways to a decarbonised world but not the COP pathway. It is always good to have discussion and debate but now is the time to face reality and take steps to eliminate the causes of climate change, starting with our own country, he concluded. □

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The debate

After the formal presentations, the speakers answered questions from the audience, on a range of topics including: young people; sustainability; procurement; critical path; skills and training.

Young people are setting a very strong example in regard to climate change, and not just by marching and taking days off school. They will shortly be in positions of influence and power themselves. Universities are already being held to account by students on this issue. But older generations have to keep pushing as well, until the next comes through the system.

Every European born between 1945 and 1965 will have been responsible for emissions on average of about 700 tonnes of carbon dioxide. To achieve a global temperature increase of just 1.5˚C or 2˚C, those born since the Millennium must emit an absolute maximum of 100 tonnes of carbon dioxide. So there's a massive change in the environmental impact of successive cohorts. Most people still do not comprehend the size of the challenge.

Sustainability data

Products on supermarket shelves have very little sustainability information on them. The data exists and it could be provided. Whether people would pay attention is a cultural issue but at least it would be available.

For many institutions, a large part of the carbon footprint is determined through procurement. There is the financial cost, but there is also an environmental cost, and these have to be balanced. Current accounting systems are not able to perform those calculations. The market will have to deliver them eventually.

Project management skills need to be applied to the challenge of implementing net zero and a critical path defined. Option management, contingency planning, probabilistic modelling and the linking of actions to outcomes are all essential elements. There is a great deal of interest in digital twins and the extent to which modelling can contribute to a more complete understanding of the full interrelationships in a system in order to act effectively.

Role of the Treasury

The role of the Treasury is critical. If Defra or the Department of Health wants to take action on diet it cannot propose a carbon tax on food because that is Treasury's sphere. Treasury is doing work on net zero and it is looking at how to include natural capital in the Green Book.

There are examples where nations have harnessed huge resources in the face of an existential threat. That kind of effort is needed here. The work of the Climate Change Committee is crucial.

Two Government Green Deals have collapsed because of insufficient investment in the training and skills needed to actually implement them. Without paying attention to adequate skills investment, programmes cannot be successfully delivered. □

FURTHER INFORMATION

COP26 (UN Climate Change Conference COP26 website) https://ukcop26.org

CGIAR www.cgiar.org

Intergovernmental Panel on Climate Change www.ipcc.ch

FST PODCASTS

COP26: Where do we go from here? - Podcast with Baroness Young of Old Scone, House of Lords
www.foundation.org.uk/Podcasts/2021/Baroness-Young-COP26,-where-do-we-go-from-here

COP26: Where do we go from here? – Podcast with Professor Sir Charles Godfray, Director of the Oxford Martin School at the University of Oxford
www.foundation.org.uk/Podcasts/2021/Professor-Sir-Charles-Godfray-COP26-Where-do-w-(1)

In a meeting of the Foundation for Science and Technology on 15 September 2021, the Director General of the European Space Agency (ESA), Josef Aschbacher, set out his vision for the future direction of ESA and European space policy.

The future of Europe in space

In his introduction, the Director-General recalled that the UK is an important member of ESA, with many strengths – on the science side, the engineering side and the project management side. ESA needs this excellence, he said. He added that ESA in turn can provide an avenue for the UK to implement its national priorities. ESA is also a gateway to the wider world because it is probably the space agency with most interactions, through projects and programmes, with other nations.

ESA is active across all aspects of space. That, he said, is unusual: many space agencies are not. It has programmes in space science, human and robotic exploration, navigation, Earth observation, telecommunications, safety and security. It is also engaged on operational programmes, such as the development of launchers. This is, he said, unique and very useful for the achievement of member state priorities.

The overall budget for ESA is around €6.5 billion, 24% of it is coming from the European Commission and the rest from member countries (the UK contributes 9.2% of the total). One of its principles is that almost all the money should go back to the supply chain and research institutions in the member states. That means the majority of the money goes back to the countries to build up programmes and activities in cooperation with other countries and other industries.

Among recent successful projects is the Solar Orbiter. It was launched in 2020, with strong UK participation and leadership. It is one of the most complex satellites exploring the sun, flying closer to it than any previous mission, in order to understand the dynamics and properties of our star. The Plato (PLAnetary Transits and Oscillations of stars) mission will be launched in 2026, looking at habitable planets in the universe, planets that have similar conditions to the Earth's – the so-called Goldilocks zone – where there is appropriate temperature variation, light levels that are favourable to life, and other characteristics which may exist in other solar systems.

Agenda 2025

He spoke about Agenda 2025[1] which outlines ESA priorities for the next few years. The starting point is that, in matters concerning space, it is important to take a long-term view. Space developments are not delivered in one year or the next. So what is the world likely to look like in, say, 2035? In the Director-General's view, space is one of the tools that will get us there. The Agenda sets out some of the immediate steps necessary in order to get there. Five priorities with targets for 2025 are listed: commercialisation; safety and security; programme challenges; ESA transformation; and ESA-US relations.

He recalled that there is a great deal of media coverage of space, but much of it emanates from the USA or China and not from Europe. And that, he said, bothered him. The reason is that space in these countries is developing very quickly, because of investment from both the private sector and also the government side: huge investments are being made to support space programmes. Individuals like Elon Musk and Jeff Bezos are putting money into space, as are many Silicon Valley companies.

China is rapidly building a space capability, at the same level as the one in Europe, while the USA has capabilities that exceed those of Europe.

Enabling our society

Space is used in many aspects of daily life: Earth observation, telecommunications, weather forecasts and navigation, for example. Without space-based technologies, modern life would not be possible. Space is an integral part of daily life for every single person in the UK and many other parts of the world, he stated.

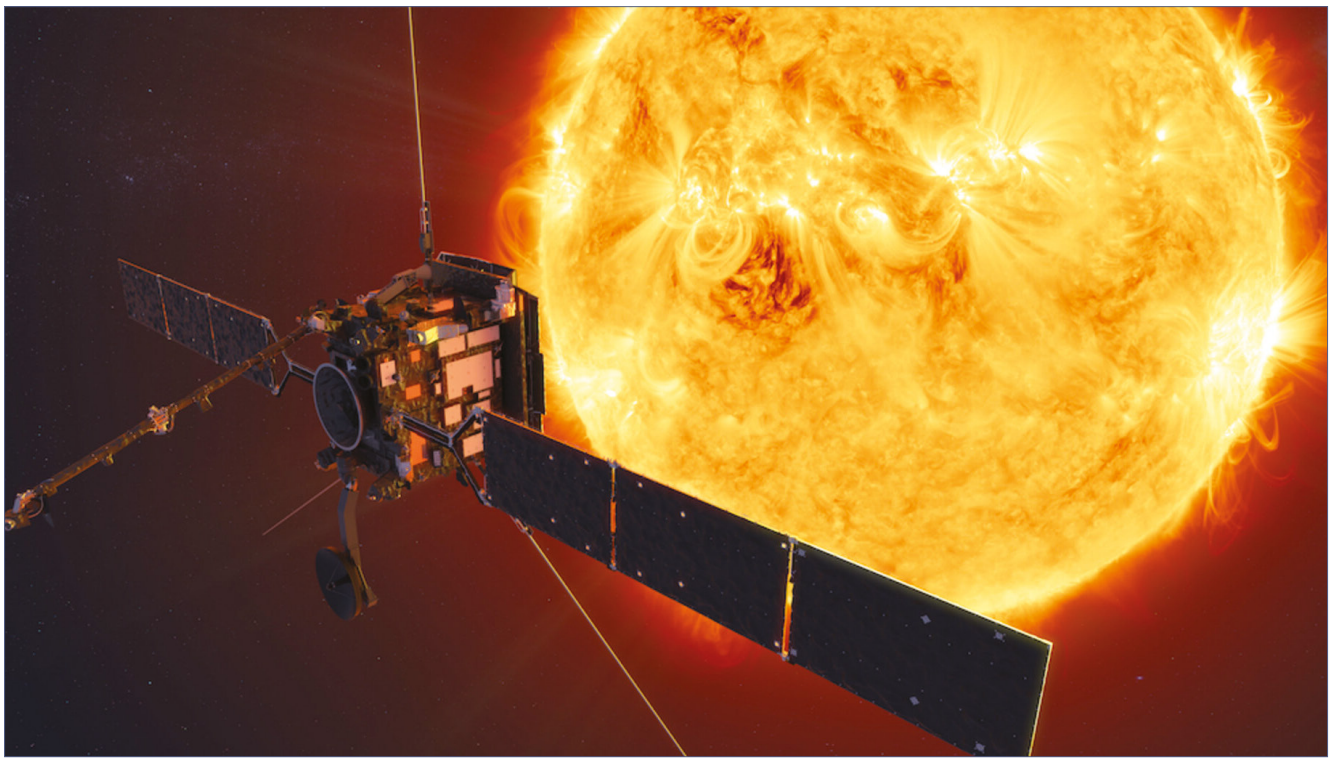
The commercialisation of space is under way. Responding and participating effectively means being able to act at speed. Access to capital is also needed to make things happen. Talent, people with brilliant ideas who are driven by those ideas and full of energy are another vital factor.

Satellites can also provide enormous amounts of data information in a timely manner both to understand what is occurring with climate change, but also to check how the world is responding. Radar satellites look through the clouds and therefore take images whenever they fly over a region. This is especially important in the case of flooding where the associated bad weather will often result in dense cloud cover. Information on flooding is then immediately available in case of crisis.

There is a rapid response system, with satellites on one side and a telecommunications network on the other, with computation done partially in space. This aids the emergency services, the fire brigades in the case of forest fires, or environmental protection agencies in case of floods, people who need the information very quickly.

Another of the Agenda 2025 priorities focusses on safety and security, specifically safety in space in the context of the dangers of space debris. Satellites are an essential part of society and need to be protected. Knowing the location of space debris enables operators to manoeuvre to avoid collisions. Mr Aschbacher suggested that Europe needs to strengthen its capabilities in this area. So this will be a focus for the next couple of years.

Space weather is another area of interest. Bursts of solar wind can impact power grids, communications networks and infrastructure, causing huge damage. It is



EUROPEAN SPACE AGENCY

Launched in 2020, the Solar Orbiter has flown closer to the sun than any previous mission.

estimated that a single event could cause economic damage in Europe in the order of €15 billion. While these are not common, they do happen and ESA is building a satellite which will give some warning when they do occur, in order to give some time to take precautionary action and protect infrastructure on the ground.

In response

Responding, Dr Alice Bunn, Chief Executive of the Institution of Mechanical Engineers, discussed how the UK might benefit from its membership of ESA. She highlighted the large-scale science and exploration infrastructure. Those huge programmes take many years to come to fruition – she cited the James Webb Space Telescope which was 25 years in the making. It makes sense, she said, to pool our expertise and our funding in order to cover the costs of these huge missions. The second area was civil operational capability. As a nation, the UK has historically under-invested in national capability. Instead, we have participated in EU space programmes. Membership of ESA can prove to be a very useful delivery path to help tip the balance and bring up UK national capability.

Sir Martin Sweeting, Group Executive Chairman of Surrey Satellite Technology, highlighted two particular areas that came out of Director Aschbacher's talk. The first was the Lunar Pathfinder project. Not only is it an interesting technological challenge to undertake in the so-called 'new space environment', but it represents a departure from the way ESA has done business in the past. Here, ESA is setting the requirements and then leaving industry to deliver it. He argued that this was a really important step – one that might not be noticed by many – because in the past, there had been a tendency for ESA to set the challenge and then tell industry how to do it. He saw the balance shifting and this would help ESA and Europe to move more rapidly. He argued that, with the advent of the private sector in space, the tempo has increased dramatically. The private sector is moving out from applications into exploration.

In terms of international collaboration, he noted that Europe is positioned physically between the USA and the East. Each has its own particular vision of how it wants to progress in space. India is an emerging player in space and there are others. He believed that Europe should therefore engage very closely, very positively with these other players because it will benefit from collaborative projects beyond its own individual means.

Paul Bate, Chief Executive of the UK Space Agency, stressed that space is a team effort. He said that it takes a team to achieve the steps we have made as a country and as a world. While member states are looking at the ESA's Agenda 2025, they will each have their own priorities too. The UK's National Space Strategy[2] sets out the Government's ambitions for the UK in space, bringing together civil and defence policy for the first time. This needs to be communicated clearly to other partners.

Communicating value

He added that the UK Space Agency needs to think like any organisation does, identifying and articulating clearly the value that it brings. He noted the need to engage with academia, international stakeholders, industry and Whitehall to make sure the organisation is doing the right things, particularly as the agenda changes in light of the strategy and the world changes as commercialisation of space gathers pace. □

DOI: 10.53289/CLKZ6562

1. www.esa.int/About_Us/ESA_Publications/Agenda_2025
2. www.gov.uk/government/publications/

CONTEXT

In September 2021, the UK Government published the National AI Strategy. The Strategy is "a ten-year plan to make Britain a global AI superpower". The three key aims of the Strategy are to invest and plan for the long-term needs of the AI ecosystem, to support the transition to an AI-enabled economy, and to ensure the UK gets the national and international governance of AI technologies right.

On 23 February 2022, the Foundation for Science and Technology held an event to discuss the AI strategy and the next steps for delivering it. The speakers were: Professor Dame Wendy Hall (Regius Professor of Computer Science, University of Southampton); Lord Clement-Jones (House of Lords); Professor Geraint Rees (Vice-Provost AI, University College London); and Professor Tom Rodden (Chief Scientific Adviser, Department for Digital, Culture, Media and Sport). A video recording, presentation slides and speaker audio from the event are available on the FST website at: **www.foundation.org.uk/Events/2022/Delivering-the-AI-Strategy-%E2%80%93-the-use-of-new-AI-tec**

Embedding AI everywhere and at every level

Wendy Hall

Professor Dame Wendy Hall DBE FRS FREng is Regius Professor of Computer Science, Associate Vice President (International Engagement) and Executive Director of the Web Science Institute at the University of Southampton. She was co-Chair of the UK government's AI Review, which was published in October 2017, and is the first Skills Champion for AI in the UK. In May 2020, she was appointed Chair of the Ada Lovelace Institute and joined the BT Technology Advisory board in January 2021.

SUMMARY

- The UK has been an AI superpower for some time
- The challenge is to help our young startups scale up
- The aim of the strategy is to embed AI across all sectors and regions
- Trust in data is a key issue for the AI community
- The strategy aims to tackle the lack of diversity in the sector.

The Hall Pesenti AI Review was published by UK Government in 2017 and it became part of the Industrial Strategy with its own sector deal and council. In 2020, the AI Council was asked to produce a roadmap for the following five years and this was published in January 2021. The Office for AI, working with us and others, then produced what was adopted as the National AI Strategy in September last year.

The UK has been an AI superpower for a long time, although it will never be as big as the USA and China. AI adoption across regions and sectors brings with it an element of levelling up. We aim to maintain the position of the UK, effectively third in the world. For a country of our size that is amazing and it is due to our legacy: we were involved in this area before it was even called AI. All our top universities have very strong AI departments, both broad and specialist. The UK's startup culture helps generate new companies, bringing growth and wealth into the UK.

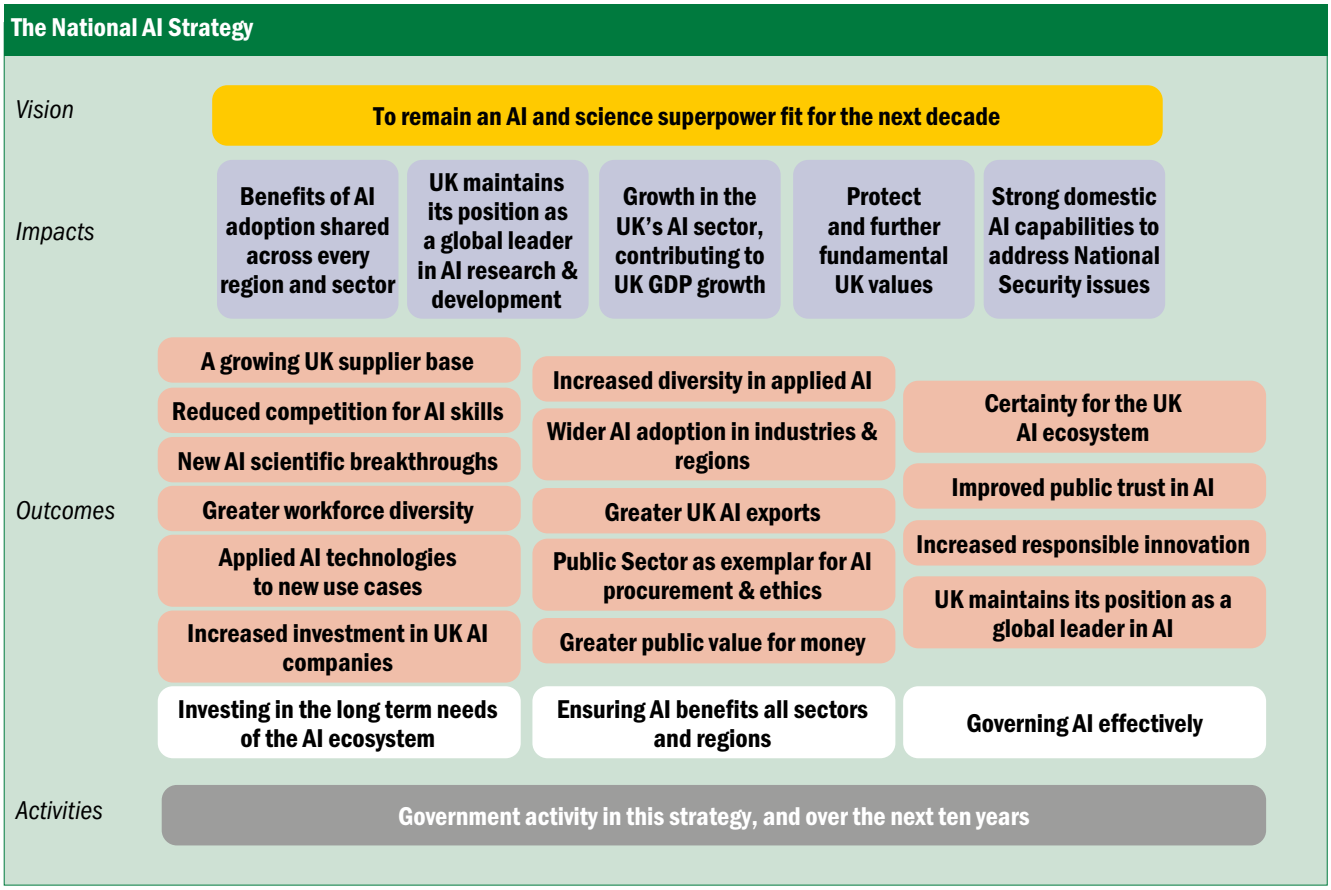
The challenge of scale

One challenge is to help those startups become bigger and scale-up. This is something that Britain has to tackle over the next few years. Take your foot off the accelerator and you just go backwards. Every country in the world is trying to be good at AI. Here, we need it to contribute to the growth of GDP. It needs to be developed in a way that protects our values, one that is good for society, good for people, good for business and for Government. It is of course vitally important for defence and security, so we need strong AI capabilities in our security agencies.

The desired outcome for the AI sector is to be developing ground-breaking technology, which can be applied in our businesses across all regions and sectors. The public sector needs to use AI to its best advantage. We want value for money for the investment being made, as well as adoption across the country. And then there is the question of trust, of people trusting AI systems – which is not easy.

This all involves long term investment, not something the UK is terribly good at. The more common practice is to provide five years' funding and then expect business to cope on its own. Yet AI will remain with us. Other technologies will come along, which will command attention, but AI is going to be with us forever.

As systems get ever more intelligent and can do more and more things, a very close eye must be maintained on what this technology is doing to society and how it works in society. So governance



will be very important as this sector develops.

The National Strategy is primarily concerned with Government activity and what needs to be done in the next 10 years. Data Trusts were the top recommendation of the 2017 review and have become a key element in the Strategy. People should be able to trust the data that someone else gives them and share it with confidence. Lots of small companies believe that the playing field is not level in this regard because those who hold large amounts of data will have an overwhelming advantage. Hence our focus on data trusts. There has been some really good pilot work done by the Open Data Institute. With the Ada Lovelace Institute and the AI Council, I chaired a study looking at legal mechanisms for data stewardship. The Royal Society was also involved and its chief executive, being a lawyer by training, took a great interest in the subject. This is becoming a very hot topic. Data is, after all, the foundation of everything we do in AI, whether machine learning or deep learning. Then there is the challenge of driving adoption across different sectors, such as healthcare, tech-nation, AI-startups, big science and purchasing.

In the international arena, the UK is part of the Global Partnership on AI (GPAI) which is a way to reach most of the world except for China. This is led by Canada and France, and the UK is heavily involved in the working groups, which gives us a way to link with many different countries. We have signed an agreement to collaborate with the USA and there are others in the pipeline.

In our initial AI review, the Alan Turing Institute was recognised as the national institute for data science and AI – and it could become a world leader in this area. Working with the Turing Institute, UKRI has funded a number of fellowships to recruit and retain AI researchers in the UK.

The National AI Strategy is primarily concerned with Government activity over the next 10 years.

At every level

We are trying to introduce AI at every level, not just Higher Education. That means skills for everybody – apprenticeships, schools, etc. The aim is that anyone can get access to AI skills whoever they are, whatever their context, whatever their background. In his spring statement, the Chancellor announced funding for another 2000 AI scholarships for MSc conversion courses which take people from non-science subjects into AI. These have been incredibly successful in promoting diversity in AI because the scholarships are targeted at under-represented groups such as women, the disabled and ethnic minorities. For me, this is the most important feature of this funding. It is so important that we increase diversity across all aspects of AI. What is not diverse is not ethical. □

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Creating the best framework for AI in the UK

Tim Clement-Jones

Lord Clement-Jones CBE was made a life peer in 1998. He is Liberal Democrat House of Lords spokesperson for Digital and a former Chair of the House of Lords Select Committee on AI. He is Co-Chair of the All-Party Parliamentary Group on AI, a founding member of the OECD Parliamentary Group on AI and a consultant to the Council of Europe's Ad-hoc Committee on AI. He is also Chair of Council of Queen Mary University London, a consultant to global law firm DLA Piper and President of Ambitious about Autism.

A little over five years ago, the Lord's AI select committee began its first inquiry. The resulting report was titled: *AI in the UK: ready, willing and able?* About the same time, the independent review *Growing the Artificial Intelligence Industry in the UK* set a baseline from which to work.

There will always be something of a debate about the definition of artificial intelligence. It is clear though that the availability of quality data is at the heart of AI applications. In the overall AI policy ecosystem, some of the institutions were newly established by Government, some of them recommended by the Hall review. There is the Centre for Data Ethics and Innovation, the AI Council and the Office for AI. Standards development has been led by the Alan Turing Institute, the Open Data Institute, the Ada Lovelace Institute, the British Standards Institution and the Oxford Internet Institute, to name just a few.

Regulators include the Information Commissioner's Office, Ofcom, the Financial Conduct Authority and the Competition & Markets Authority, which have come together under a new digital regulators' cooperation forum to pool expertise. The Court of Appeal has also been grappling with issues relating to IP created by AI. Now regulation is not necessarily the enemy of innovation. In fact, it can be a stimulus and is the key to gaining and retaining public trust around AI, so that we can realise the benefits and minimise the risks. Algorithms have got a bad name over the past few years.

I believe that AI will actually lead to greater productivity and more efficient use of resources generally. However, technology is not neutral. We should be clear about the purpose and implications of new technology when we adopt it. Inevitably, there are major societal issues about the potential benefit from new technologies. Will AI better connect and empower our citizens and improve their working life?

We should be clear about the purpose and implications of new technology when we adopt it. Will AI better connect and empower our citizens?

In the UK, there is general recognition of the need for an ethics-based regulatory framework: this is what the forthcoming AI Governance white paper is expected to contain. The National Strategy also highlights the importance of public trust and the need for trustworthy AI.

SUMMARY

- AI is becoming embedded in everything we do
- We should be clear about the purpose and implications of new technologies
- There is a general acceptance of the need for a ethics-based regulatory framework
- The Humanities will be as important as STEM in the development of AI
- Every child leaving school should have an understanding of the basics of AI.

The legal situation

The Government has produced a set of transparency standards for AI in the public sector (and, notably, GCHQ has produced a set of AI ethics for its operations). On the other hand, it has also been consulting on major changes to the GDPR post-Brexit, in particular a proposal to get rid of Article 22, the so-called 'right to explanation' where there is automated decision making (if anything, we need to extend this to decisions where there is already a human involved). There are no proposals to clarify data protection for behavioural or so-called inferred data, which are the bedrock of current social media business models, and will be even more important in what has been described as the metaverse. There is also a suggestion that firms may no longer be required to have a Data Protection Officer or undertake data protection impact assessments.

We have in fact no settled regulation, or legal framework, for intrusive AI technologies such as live facial recognition. This continues to be deployed by the police, despite the best efforts of a number of campaigning organisations and even successive biometrics and surveillance camera commissioners who have argued for a full legal framework. There are no robust compliance or redress mechanisms for ensuring ethical, transparent, automated decision-making in our public sector either.

It is not yet even clear whether the Government is still wedded to sectoral (rather than horizontal) regulation. The case is now irrefutable for a risk-based form of horizontal regulation, which

SHUTTERSTOCK/ ANDREY_POPOV

We have no settled regulation, or legal framework, for intrusive AI technologies such as live facial recognition.

puts into practice common ethical values, such as the OECD principles.

There has been a great deal of work internationally by the Council of Europe, OECD, UNESCO, the Global Partnership on AI, and especially the EU. The UK, therefore, needs a considerable degree of convergence between ourselves, the EU and members of the Council of Europe, for the benefit of our developers and cross-border businesses, to allow them to trade freely. Above all, this means agreeing on common standards for risk and impact assessments alongside tools for audit and continuous monitoring for higher-risk applications. In that way it may be possible to draw the USA into the fold as well. That is not to mention the whole defence and lethal autonomous systems space: we still await the promised defence AI strategy.

AI skills

AI is becoming embedded in everything we do. A huge amount is happening on supporting AI specialist skills development and the Treasury is providing financial backing. But as the roadmap produced by the AI Council itself points out, the Government needs to take further steps to ensure that the general digital skills and digital literacy of the UK are brought up to speed.

I do not believe that the adoption of AI will necessarily make huge numbers of people redundant. But as the pandemic recedes, the nature of work will change, and there will be a need for different jobs and skills. This will be complemented by opportunities for AI, so the Government and industry must ensure that training and retraining opportunities take account of this. The Lords AI Select Committee also shared the priority of the AI Council roadmap for diversity and inclusion in the AI workforce and wanted to see much more progress on this.

But we need however, to ensure that people have the opportunity to retrain in order to be able to adapt to the evolving labour market caused by AI. The Skills and Post-16 Education Bill with the introduction of a lifelong loan entitlement is welcome but is not ambitious enough.

A recent estimate suggests that 90% of UK jobs within 20 years will require digital skills. That is not just about STEM skills such as maths and coding. Social and creative skills as well as critical thinking will be needed. The humanities will be as important as the sciences, and the top skills currently being sought by tech companies, as the University of Kingston's future league table has shown, include many creative skills: problem solving, communication, critical thinking, and so on. Careers advice and Adult Education likewise need a total rethink.

We need to learn how to live and work alongside AI. The AI Council roadmap recommends an online academy for understanding AI. Every child leaving school should have a basic sense of how AI works. Finally, given the disruption in the job market, we need to modernise employment rights to make them fit for the age of the AI-driven gig economy, in particular by establishing a new dependent contractor employment status, which fits between employment and self-employment. □

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The human dimension in the AI ecosystem

Geraint Rees

Professor Geraint Rees FMedSci is Pro-Provost (Academic Planning), Pro-Vice-Provost (Artificial Intelligence) and Dean of Life Sciences at UCL. He is UCL's strategic lead for AI and leads the development of UCL's 'AI for People and Planet' strategy. As a Director of UCL Business and a former Senior Scientific Advisor at DeepMind, he is also deeply involved in commercialising AI technologies. He shapes training of the next generation of AI healthcare expertise as co-Director of the AI-Enabled Healthcare Systems Centre for Doctoral Training at UCL.

SUMMARY

- Technology exists and is developed within societies
- Successful application of AI will involve a number of disciplines
- Fairness and bias are challenges for AI
- In some important areas such as healthcare data does not always provide the answer
- Universities can play a role in bringing disparate elements of the ecosystem together.

Delivering strategic advantage through the National AI strategy will depend on us thinking more about people than about the technology. At the start of the pandemic, we were told that AI would change the world and I am confident it still will.

Despite the outstanding efforts of staff in adapting to deliver teaching and learning online, students have been clear that they would like to return to face-to-face education and shared campus experiences. Advanced technology and innovative blended approaches will remain part of their education, but students also demand human interaction in our great seats of learning.

It is clear that artificial intelligence and associated technologies are a really important part of our shared future. Applied mathematics and computer science have had a crucial role in addressing some of the consequences of our enforced isolation. Yet that technology comes into existence on a planet already populated by human societies. I would echo the OECD statement: "AI should be for people and planet." UCL indeed makes this insight the centrepiece of its AI strategy, trying to position AI as a force for good in the world through considering the human dimension, inclusion and diversity.

A blended approach to the future does, though, have implications for the kind of workforce that will be needed. Today, the conventional means of delivering machine learning and its benefits directly to individuals involves a browser and computer screen. In such an environment, the answer to any question might seem to be: we need more software engineers. But the specific environments in which humans live and work are much messier and more uncontrolled. Mastering successful interactions often requires domain-specific knowledge. Think of going to the doctor or a hospital for example: if the answer to the question is more software engineers, then we have not really properly understood the question.

Many disciplines

Successful delivery of the benefits of AI will depend on many disciplines.

Successful delivery of the benefits of AI in every sector will therefore depend on many disciplines. It is necessary to recognise the central role of the Arts and Humanities in understanding and interpreting human experience, and the part of the Social Sciences in helping to shape how AI might fruitfully interact with people in society.

For example, medical applications will clearly benefit from structured interaction between doctors, healthcare professionals, computer scientists and software engineers. A project by Google DeepMind, on acute kidney injury, where the medical condition is identified through a longitudinal time series analysis of healthcare data, picks out what medical professionals know is one of the most common causes of unexpected deterioration in a patient's condition in a general hospital anywhere in the world. It provides an algorithm with general applicability. And it came about not by chance, but because medical professionals worked together with DeepMind in a systematic and structured way.

In bringing together the required skills across different sectors, there are two obvious approaches. Either train a single individual in both areas, or bring together individuals with complementary skills. However, training clinician computer scientists is still in its infancy and individuals with these skills are pretty rare. The alternative approach is not just about putting people in the same room and hoping they get on with it, though. Universities as well as other bodies are improving their ability to create interdisciplinary dialogue.

Yet there are risks. In the USA, rapid deployment of electronic healthcare record systems has taken place over the past decade. This has not unfortunately created a technological nirvana of elegant, unobtrusive and effective data capture

SUTTERSTOCK/SCIEPRO

Medical professionals worked with Google DeepMind to identify acute kidney injury through a longitudinal time series analysis of healthcare data.

from healthcare consultations. Indeed, a much more challenging situation has emerged. Essentially, instead of making healthcare easier and effective, many doctors feel trapped behind their screens, spending about two hours on computer data entry for every hour spent face-to-face with the patient. Now that should not be the future of AI.

Bias

Fairness and bias are topics of enduring interest in human societies. It is surprising that the discipline of artificial intelligence has only recently recognised that it has a significant problem here. Machine learning systems based on historical or incomplete data have duly learned to produce unfair results. Examples include corporate HR tools that are prejudiced against women, as well as gender and dialect bias in automated captioning. These are shocking examples, but they hide even deeper challenges as AI progresses to consider complex issues like fairness in healthcare.

Both model performance and healthcare outcomes depend in part on an unknown combination of biological, environmental and economic factors. Indeed, some level of modelled performance that differs across a specific group may be desirable, say, if a particular ethnic group is more susceptible to a specific disease. Unlike the earlier examples, a major problem affecting that sort of machine learning is the absence in many – perhaps most – cases of any reliable ground truth. Unlike other areas of machine learning, where data can be labelled by humans with a high degree of accuracy, medical diagnoses are fraught with uncertainty. Indeed, some conditions essentially exist as social constructs based on constellations of symptoms, whose underlying causes are not fully known, or agreed, and change over time.

Such challenges may not be overcome by a particular ethical code. Instead, they are conceptual and fundamental. So the development of AI is not just about ethical frameworks and conceptions of how we might address bias. We might wish to invest in R&D to develop agreed frameworks that explore, quantify and correct model performance across particular populations. How that correction is applied is fundamentally a question about what is fair, rather than a computable function.

The AI roadmap sets out how AI can benefit every sector in every region of the UK. No organisation can undertake this alone. Rather, a complex combination of infrastructure, expertise and entrepreneurship is needed across the AI ecosystem. That does not happen by accident: it happens in particular locations and in response to particular sets of incentives.

Partners

This happens again and again in cities. My own university was founded in London in 1826. Other European institutions were founded at the same time. There was a huge flowering of talent and activity in the natural and life sciences. Every region of the UK contains at least one world-leading comprehensive university, an anchor partner in its city for jobs and independent innovation, deeply embedded in its local environment and culture. They have a crucial role in bringing together the different elements that will enable us to compete on a global stage. □

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A complex combination of infrastructure, expertise and entrepreneurship is needed across the AI ecosystem.

Ensuring AI is embedded in all sectors and regions

Tom Rodden

Professor Tom Rodden is Chief Scientific Adviser to the Department for Digital Culture Media and Sport (DCMS) and a Professor of Computing at the University of Nottingham. Prior to joining DCMS he was Deputy Executive Chair of EPSRC where he was responsible for research strategy and acted as the UKRI lead in both AI and e-infrastructure, driving several large-scale initiatives that span multiple disciplines across UKRI. He is a fellow of the Royal Academy of Engineering, a Fellow of the ACM and the BCS.

SUMMARY

- Investment levels must be maintained if we are not to fall behind our competitors
- AI needs to become a part of our everyday lives
- Diversity and skills need to be promoted at all levels
- Standards for AI will be critically important
- International cooperation and coordination will be crucial in the coming years.

The National AI strategy highlights a number of important factors. One key item is the level of investment. Some £2.3 billion has already been invested in AI. That level of support has to continue. Another priority highlighted in the Integrated Review, is the drive to complete the transition to being a science superpower.

AI technology is developing fast, it is advancing quickly and we must not slow down or take the foot off the accelerator. Our academic and research base is making major advances which need to be transferred quickly into commercial success and value for the UK.

The National Strategy sets out how AI can move from being a distinct technology to something that is integral to society, a part of society, incorporating the values we have and working for us. Future AI will need to be a partnership between people and the technological elements.

The international position is also important. A large amount of resource has been spent on different aspects of AI across the world and the UK needs to be selective and strategic in its engagement.

Diversity and trust are located at the very heart of the Strategy. There are then three pillars: the first is investment in the long term needs of the ecosystem. This is critical: the AI ecosystem does not simply emerge, it needs to be grown. The second is fairness: a vital element. The pandemic has highlighted an exacerbated lack of fairness and diversity across the UK. We must ensure that benefits accrue to all and to every sector and region equally.

Effective governance

Then, there is the need for effective governance. What are the underlying drivers for building the ecosystem and what are the mechanisms to make this happen? Diversity and skills need to be promoted at all levels. We do not want an AI that reflects a privileged, white middle-class view. Rather, the AI of our society should represent a diversity of views, a diversity of perspectives and a diversity of backgrounds.

Many of the issues facing AI have their roots in philosophy and epistemology, not in mathematics. We really need to think carefully about what we mean here by 'AI' and by 'intelligence'. These are not simple concepts and they need to be properly analysed.

AI research and innovation need to be at the core of what we are attempting and need to be coordinated and focussed. Transdisciplinary and multidisciplinary approaches must work together and link to industry as well. Appropriate tools are needed to achieve this. ARCHER2, the UK National Supercomputing Service, has now been switched on: we need this level of computational power in the UK in order to achieve our goals. In addition, we need to work out the best way to use data, including Government datasets and the data of our citizens.

There are a large number of industries in the UK that are updating their data skills with AI technologies. But specifically we need SMEs across all sectors to adopt new, modern AI tools: this will be a critical driver in terms of maturing the benefits of these advances. Giving businesses access to the necessary level of skills and expertise is going to be important, particularly for companies who cannot create their own AI department, or hire their own AI expert.

Government has to identify those parts of its own activities where AI can make a difference. These include critical missions, such as net zero and the health of the nation, where AI can be used and showcased.

Finally, governance is a crucial issue. Standards for AI are going to be critically important. They will form and shape the nature of AI going forward. As a nation, we must embed our values within those standards while providing genuine leadership on a global AI standardisation landscape.

Defining AI is really challenging. How then

We need SMEs across all sectors to adopt new, modern AI tools: this will be a critical driver in terms of maturing the benefits of these advances.

do you standardise something that is notoriously hard to define and in so doing establish and promote good practice? Current initiatives are looking at standardisation from different perspectives, so bringing these all together will present a challenge. Building or using an AI system may involve a choice between six or seven different guidelines. Some degree of coordination will be essential. This is a role for Government, promoting best practice and approaches to governance.

The Office for AI is seeking to address all the challenges of AI across Government. It is working through its action plan, consulting with Government, industry and others. The Strategy is a good vehicle to promote coordination.

We need to think carefully about international cooperation. That will develop in various ways over the next five to six years, particularly in terms of the partnerships we build. International cooperation, for many people, involves nation states. Yet the emerging technical AI superpowers may not be nation states and we may have to revisit our approach to international cooperation and relationships as we go forward. □

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Building or using an AI system may involve a choice between six or seven different guidelines.

The debate

How far is AI embedded in society and the economy – what are its successes and shortcomings? The comment was made that when AI is a success and becomes embedded, it ceases to be referred to as 'AI'. A host of specific AI successes were cited, including those within FinTech, EdTech and agriculture. AI will surely have a huge impact on the delivery of the Sustainable Development Goals. As an emerging technology – or family of technologies – there are a number of issues around regulation and standards, especially given the speed at which the sector is growing and diversifying.

Fraught standards

As it is difficult even to agree a definition of AI, developing standards for this area is fraught with difficulty too. Yet, following the rapid emergence of AI centres across Government, academia, and the wider world, there is a critical need for appropriate regulation and identification of adequate governance mechanisms. It is likely the case that a single regulator will not suffice and that domain-specific bodies – particularly in the case of medical data, for which informed consent cannot be given at the time of sample collection – may be required if the consent relationship is to be based on trust, rather than transaction.

On the subjects of effective governance and engagement with multinational businesses, the Global Partnership on AI (GPAI) is a useful forum for collaboration. The Capital Economics report on AI Activity in the UK suggested that there may be a skills shortage of 50-100,000 skilled people in the future. An alternative view was that there is a need for experts to remain within their own sectors and interact with AI specialists, rather than transitioning large numbers of experienced people into this new field. Whereas there has been concern over the loss of jobs as a result of widespread adoption of AI, it now looks likely that there will instead be a host of new positions and skills created, starting at the apprentice level.

AI will make a key contribution to several of the major challenges currently facing the world. With regard to defence, international treaties, similar to those for nuclear proliferation, were advocated as a strategy for collaboration with international partners that may have different ethical standards. Similarly, the climate challenge represents another area in which AI can prove beneficial, albeit with careful consideration required to overcome the energy consumption associated with technologies such as Web 3.0 and blockchain.

Overall, the field of AI represents an opportunity to enhance a number of sectors in the UK, and beyond, and the AI Strategy will be key to ensuring that this is done safely, responsibly, and ethically. □

After the formal presentations, the speakers came together in a panel to discuss relevant topics with members of audience, including: the success of the technology to date; standards; governance; and collaboration on global challenges.

FURTHER INFORMATION

National AI Strategy
www.gov.uk/government/publications/national-ai-strategy

FST PODCASTS AND BLOGS

Artificial Intelligence - Podcast with Dr Kate Devlin, Reader in Social and Cultural Artificial Intelligence at King's College London
www.foundation.org.uk/Podcasts/2022/Dr-Kate-Devlin-Artificial-Intelligence

CONTEXT

The UK Government has a target to reach net zero emissions by 2050. This will require a huge increase in electricity on the grid. As we move to electric vehicles, heat pumps for domestic heating, and power generation from renewable sources, there are implications for the UK electricity grid, the way it is structured and how it needs to change and adapt to meet a decarbonising society.

On 23 March 2022, The Foundation for Science and Technology held an event to discuss these issues. The speakers were Nick Winser (Chairman, Energy Systems Catapult), Dr Cathy McClay (Trading and Optimisation Director, Sembcorp Energy UK) and Professor Keith Bell (Scottish Power Professor of Smart Grids, University of Strathclyde). A video recording, presentation slides and speaker audio from the event are available on the FST website at: **www.foundation.org.uk/Events/2022/Rebuilding-the-UK-Electricity-Grid**

Building the electricity grid of tomorrow

Nick Winser

Energy Systems Catapult Chair since 2015, Nick Winser CBE FREng was appointed Chair of the Advisory Board for the Energy Revolution ISCF programme in 2018 and served on the Advisory Panel for the Cost of Energy Review in 2017. He is also a member of COP26 Science Priorities Task & Finish Advisory Group and the Net Zero Expert Group which advises the Secretary of State. He is a member of the IET, serving as its President in 2017-18.

SUMMARY

- Electricity demand is expected to increase dramatically as the UK decarbonises
- Demand management will be needed to reduce overall demand on the system
- The grid will be connecting a different mix of electricity generating facilities in future
- Digital technologies can now enable a much smarter approach to balancing supply and demand
- A smart grid will allow supply to be controlled from the bottom up, instead of the traditional top-down approach.

The current most likely route to decarbonising the UK energy system would probably lead to demands on the electricity grid in the order of three times as much demand as today. To address that increase using today's structure, with more wires, transformers and substations would take decades, and cost many billions of pounds.

The existing grid was built in very different circumstances where, for example, pylons striding through the countryside were largely welcomed back in the 1960s and 70s. Attitudes have changed. Building new transmission lines, for example, to Hinkley Point nuclear power station incurs significant sanctioning and planning permissions. Therefore, this country will need an entirely different approach for the grid of the future if it is to distribute a great deal more electricity.

Currently, electricity provides in the order of 20% of end-use demand. The most likely decarbonisation routes for transport and domestic heating are likely to be via electric cars and heat pumps. Undoubtedly, other technologies will have major roles, particularly hydrogen and biofuels, but whichever way you look at, electricity demand is going to increase substantially. With biofuels, supply will be limited by land use considerations. For hydrogen, scarcity of green electricity to make green hydrogen is going to remain an issue for decades. So, decarbonisation of our existing electricity footprint will take a long time, never mind a substantial increase.

Biofuels and hydrogen are likely to be used where they really are the best solution: in aviation, industrial heat and heavy transport. Now, one technology which can take one unit of scarce precious green energy and turn it into three should create some excitement. Heat pumps are a fantastic resource in a world where green energy is going to be so short – but they do not grab people's imagination. There is no doubt hydrogen could provide significant amounts of domestic heat, probably via industrial applications.

In a world where green electricity is either directed to heat pumps or into making green hydrogen, there will need to be a significant increase in wind farms (even with substantial encouragement to technologies like nuclear). However, for the same quantity of power, five times as many wind turbines are needed with hydrogen as with heat pumps, because electrolysis is 70% efficient while heat pumps are 300% efficient. The maths is quite easy.

The scale of this challenge for the grid requires

ISTOCK/SPICYTRUFFEL

Much new demand is quite different in nature from typical applications today such as being able to turn the kettle on for an instant cup of tea. Some of the new demands, such as car charging, are much more flexible in terms of when they are required.

a consideration of demand management – i.e. making it smaller – particularly by driving forward building energy efficiency. The UK is desperately overdue for a robust assessment of the potential for improving efficiency on new buildings and also on retrofits.

The grid is changing as well, from large, relatively remote (but inland) fossil fuel generation, to a blend of very remote, very large offshore wind farms and nuclear power stations, plus a plethora of small and very small, local distributed sources. Overall, the number of sources will multiply, increasing the challenge of grid coordination.

With the intermittency of renewables, what used to be an installed capacity of 60 gigawatts has risen to over 100. This is because the utilisation factor of renewables is much lower. Even when wind farms are at 30% utilisation when the wind is blowing, the grid has to be at full capacity in order to use it. So not only does the size of the challenge need to be reduced, we have to think of other solutions for the demand that remains.

Luckily, there is a variety of opportunities to help reduce the challenge. There are new technologies and new ideas to make the grid work efficiently without three times as many wires, transformers and substations.

Much new demand is quite different in nature from typical applications today such as being able to turn the kettle on for an instant cup of tea. Some of the new demands are much more flexible in terms of when they are required: car charging, for example, or heat pumps where consumption can be displaced in time with a smart energy system.

Smart energy systems will be needed to defray the large investments that are entailed. Local, distributed generation sources will also reduce intensity in grid loading. Everyone is used to a grid system that drives the flow from high voltages down to low voltages and that is where the constraints are. To address this, we will need to develop and deploy new storage technologies. Our current energy system, after all, is also based on stored energy. That is what fossil fuels are. This storage characteristic will need to be replicated.

A smart grid system powered by digital and communication technologies will optimise the grid, not from top down as has been done historically, but from the bottom up. To support this, a number of changes are needed to the management of our energy systems, including a real focus on innovation. Vigorous engagement with customers enables grid optimisation while satisfying their needs for energy in their daily lives. More granular energy markets will encourage that very detailed optimisation both in planning and operations. Local energy plans in every part of the country will help to make the most of the resources that are there.

The future electricity system will need a very different approach to building out the grid because of the new demands on it. This must be based on a changed approach to institutional architecture and the deployment of digital and communication technologies in order to balance the grid from the bottom up. □

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A smart grid system powered by digital and communication technologies will optimise the grid, not from top down, but from the bottom up.

The role of wind in decarbonising the grid

Cathy McClay

Dr Cathy McClay FREng OBE is Director of Trading and Optimisation at Sembcorp Energy UK. Over her 20 year career, she has worked for energy companies in the UK, France and the Netherlands, specialising in modelling and analysis for energy trading, risk management, strategy and investment. Immediately prior to joining Sembcorp she was Head of Future Markets at National Grid ESO. She is a Visiting Professor at Imperial College and a Fellow of the Royal Academy of Engineering. In 2022 she was awarded an OBE for services to the Energy Sector and Promotion of Decarbonisation.

SUMMARY

- There is an aspiration to have 40GW of installed wind energy capacity by 2030
- The system is incurring substantial costs due to an inability to export energy from, for example, Scotland to England
- New wires will be required, but combined with smart technologies to optimise the system
- Building new lines takes a long time, but some anticipatory planning could help
- We need to be bolder in our targets and projects.

The UK is now looking at an electricity system where demand will be much higher due to decarbonisation. Yet that brings many challenges with it. Take for example the impact of wind on the system. Decarbonisation is going to be reliant on a great deal of offshore energy. On our system right now, there is about 100GW of generation servicing a peak demand of about 40-50GW on the transmission system. Within that, there is currently 25GW of wind, split pretty equally between onshore and offshore.

There is an aspiration to achieve 40GW of offshore wind by 2030. That is an increase of 28GW more than is currently connected on the system in total. Now, 2030 is only eight years away, it is not far. System operators expect there will be 30-40GW of generation in Scotland by then, if conventional technologies are used. Demand in Scotland is likely to be just 6GW. The rest of that power has to be transferred out of Scotland. Yet the current transfer limit of power to England is 6GW, after which the wires start overheating.

Of course, even with 30-40GW of generation in Scotland, it will not be producing the whole time. There is 25GW of wind on the system now but the peak I normally see is about 15GW and the lowest over the past year was 200MW. That is a very big swing to manage on the system!

A lot of the time, it is just not possible to get the power out of Scotland. Wind farms are being built but the output is wasted. Whenever power cannot be transferred, that incurs costs. Firms want to generate because every megawatt hour is paid for under their Contract for Difference or their Renewable Obligation Certificate. Instead, they are being paid £80 pounds per megawatt hour to switch off. The cost of those constraints on the system at the minute is about half a billion pounds a year.

System operators expect the cost of managing the system to rise to between £1 billion and £2.5 billion over the next five years because of these constraint costs. Windfarms are being built right now that cannot be used. What can we do about that? The first option is to attract more demand into Scotland, to take advantage of the surplus production. That could be achieved by setting a price reflecting the fact that wind energy in Scotland is not as valuable right now, because we cannot get it out. Perhaps technologies like hydrogen electrolysers could be brought in.

It may be possible to use the wires between Scotland and England more effectively and get more out of them by being smart in the way they are used. The transmission operator has managed to upgrade the transfer without actually building more wires. The final solution is to build more wires as well, but hopefully fewer wires because smart technologies are being introduced at the same time. The challenge with building lines is the time it takes: getting planning permission alone can take years. The first proposal is to build a line down the East Coast from Peterhead to Drax of two gigawatts. A second would take energy from Torness on the east coast of Scotland down to Hawthorne Pit near Durham.

Now, the system operator has been asking transmission companies to go ahead and build these two lines since 2018. Yet they only got regulatory approval in 2021. The proposals are now going through planning and are expected to be online in 2029 and 2030. That is more than 10 years since they were given the initial go-ahead. Indeed, the projects were first suggested in 2011, although at that point the network was very different: no-one envisaged all this offshore wind.

The new capacity will have to be built more cleverly. Today's offshore windfarms are each connected to the coast independently. That means a large number of connections and they all need planning permission. There is no redundan-

cy because there is only one connection onto land. What could be done differently?

The Offshore Transmission Network Review looks at how to build a grid in the North Sea. The system operators have been asked by Government to meet the objective of connecting 40GW of offshore wind by 2030. The plan would be, instead of connecting each one separately, to look at this holistically and connect a network. The estimate for capital reduction of such an approach is £6 billion over the lifetime out to 2050, with only half of the onshore assets needed compared to conventional practice.

In terms of the system, there is a need to build more wires. It must be done cleverly, though, and more quickly if we are not going to waste the resource. What do we need to be able to do that? First, we need joined-up thinking. The UK has said it will build a lot more windfarms. But there has been no discussion of the wires that go with it, for example. So to realise the offshore potential, joined up-thinking is important and the Offshore Transmission Network Review will play a key role.

So often, though, we come up with good ideas and then do not really commit: in this case we really must. To be successful needs joined-up thinking between the system operator, the regulator and Government. We probably also need a bit more central planning. At present, the system operator advises on what lines should be built through their networks options assessment process every year. But it is only advice, there is no compulsion behind it. The network operators do not have to agree or act on the advice. The system operators are in the process of splitting away from National Grid and forming an overall independent system operator. Perhaps the new body could take on the planning role.

Finally, we need to be a bit bolder in what we do. Building wires takes a long time with planning processes, etc. If we wait until we are absolutely certain we need a new line or something else before we build it, then it will arrive too late. Anticipatory planning would go some way to smoothing and speeding up this process. Being just a bit bolder will help us get to net zero. □

The UK has said it will build a lot more windfarms. But there has been no discussion of the wires that go with it.

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A net-zero electricity system

Keith Bell

SUMMARY

- The electricity system is moving to greater use of weather-dependent renewables; these have highly-variable availability and use power electronics to connect to the network
- This requires a change of approach from traditional network management
- Flexibility, schedulability and persistence are key characteristics in ensuring that demand can be met reliably
- Upgraded transmission capacity is needed to optimise flows of energy
- Investment in knowledge and skills is essential for success.

The electricity system is changing towards greater use of variable renewables – wind and solar as well as hydro. Wind and solar are connected to the network using power electronics, which are also used by subsea interconnectors between Britain and other countries. Sources of power connected in this way are termed 'inverter-based' resources.

These contrast with the traditional system based on the big thermal power stations of previous years, which created a great deal of heat to produce steam under high pressure to turn a turbine, which uses a synchronous generator to generate the electricity.

The challenge is to make efficient use of whatever low-carbon energy is available, when it is needed. There are a number of issues to be addressed in order to make that happen, not least an ability for the system to survive disturbances such as equipment faults or unexpected variations in weather. Look around the world and there is a national or regional blackout somewhere a number of times every year. We have to make sure that it does not happen here, although the possibility will always be there.

One particular event in August 2019 – triggered by a lightning strike on an overhead line, something that is not uncommon – led to disconnection of 1.1 million electricity customers across England and Wales. It had a particular impact in the South East of England, affecting trains that experienced a drop in the frequency of the elec-

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MCGILL

Solar panels on roofs can help to manage variations in the system, but the system operator needs better monitoring of the connected supply.

tricity system to well below 50Hz which activated protection devices on the trains and made them stop. Technicians had to go out with laptops to restart them.

This particular event highlighted what happens if system frequency is not adequately managed and kept within acceptable operating limits. Equipment is designed only to operate within certain limits and will trip if these are breached. A cascade can then occur which results in a blackout. On this occasion, the lightning strike caused losses of generation that should not have happened but resulted in the fall of frequency. Other devices that should have responded to correct the fall in frequency failed to do so. If either of those errors had not occurred, 1.1 million customers would not have been disconnected.

Although many of the new technologies present new challenges to the system operator, the linking of a variety of sources of energy with power electronics and appropriate controls provides the opportunity to respond quickly and stabilise the system. The system operator is aware of this and is working on stimulating the market to provide the necessary services.

Synchronous generators create current, which is very dangerous when there is a short circuit on the network. However, they do enable automatic identification of where that fault lies, so that it can be isolated safely with the appropriate equipment before the whole system shuts down. Simply dispensing with all that synchronous plant might mean that faults are sometimes not identified and cleared in the right way: this could threaten the stability of the system. Again, there are things that can be done about it by changing the characteristics of the power electronic controls, or the algorithms in the protection equipment.

Local distributed generation, from solar panels on roofs to modestly sized Combined Heat & Power (CHP) units, can also help to manage variations in the system. However, to be an asset in this respect, the system operator needs a better understanding of that potential, including better monitoring of the connected supply, so that it can be integrated into the overall control capability for the grid.

The question of renewables

Nowadays, the cost of producing electricity from wind and solar is lower than from any other source in Britain. However, there are days when there is a lot of wind and sun, while on others there is not so much. At Strathclyde, we analysed all these variable renewables and how their availability coincides with demand for electricity. The difference between demand and the availability of variable renewables is the 'residual demand'. Plotting this for each simulated hour of 2030 showed that there are challenges for the grid at both ends of the curve, when residual demand is high and when it is low.

When it is not windy and sunny, what else are can be used to meet the demand for electricity? There may also be times when there is a generation surplus, i.e. the residual demand is negative. We do not want to waste that really useful, low-carbon output. Storage could be a big part of the answer for both temporary shortage or surplus, whether it is stored hydrogen manufactured via low carbon means, compressed air, or something else. With a substantial increase in the number of electric vehicles with batteries plugged in at home every evening, perhaps we could use the stored energy in those batteries?

We need flexibility, of course, to meet changes of residual demand and fill any gaps. Flexibility means being able to adjust production or consumption quickly and at short notice. We need schedulabilty where we can schedule power to be produced at any given time on a given day in the future, including calm, dark days. And the system also needs persistence where increases in production or decreases in consumption can be sustained for a period of time, producing not just a certain instantaneous level of power but a significant amount of energy over a number of hours or days.

Network capacity

It is not possible to use all of the wind power produced north of the border within Scotland. Network constraints mean exports frequently have to be reduced, wind output turned down and something else – more expensive and usually fossil-fuel based – used in England. The network between Scotland and England has been upgraded in recent years but more capacity is needed. Installing more cables under the sea down the East Coast has been proposed but they have not been built yet. Further,

it is not just the offshore links that are needed – more connections are needed onshore, too, in order to reach the places where electricity is used.

Power electronics is a very flexible technology, but much of it is currently designed in ignorance of what else is on the system. This pretends that the system is some sort of ideal network. In the real world, everything interacts with everything else. From time to time, they interact adversely and oscillations appear almost out of nowhere. These inverter-connected resources bring lots of opportunities but also challenges, including questions of commercial confidentiality for proprietary developments of their controls. We also need new tools and methods so that the system operator can ensure that all the parts of the system behave in a predictable and stable manner.

To sum up, there are fantastic opportunities, which we should be realising. Work is already underway on many of them and substantial progress is being made. The one overarching issue is to ensure enough investment in getting the right knowledge and skills within the sector to resolve these challenges. □

Power electronics is a very flexible technology, but we pretend that the system is some sort of ideal network. In the real world everything interacts.

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The debate

After the formal presentations, the speakers came together in a panel to discuss relevant topics with members of audience, including: demand flexibility; intermittency; hydrogen and tidal power.

Although electricity demand is projected to triple over the coming years, demand flexibility will be very important for minimising supply requirements on the grid: the flatter the load curve, the better. Decades ago, Economy 7 helped to do that with domestic demand. This led to storage heaters as standard items in houses. There are lots of technologies that can help move demand and so remove some of the peaks in demand. Today, heat batteries, which use phase change materials, along with heat pumps, can perform a similar role in shifting the heat load.

Another issue, given current grid constraints, is the matter of siting demand and supply closer. Is localised generation going to be better overall than large plants that cost less to generate per megawatt but which are not accessible? Another option would be to move industry closer to generation centres.

One of the biggest problems that has still not been solved and needs to be tackled in order to optimise the future grid is that, looking at the amount of renewables that will be installed on the system, a great deal of extra capacity is needed to compensate for intermittency. In summer, weather conditions usually result in an excess of wind and solar generation. The challenge is how to store that so that it can be used in winter. Is seasonal storage at scale even possible? Storage will be critical to the energy future because it is replacing the inherent storage of fossil fuels.

Hydrogen storage is likely to be extremely economic in some applications, particularly industrial complexes, trains and heavy goods vehicles. Green hydrogen could also be used in many industrial processes like steel production, which are currently dependent on fossil fuels. So it may be more important for industrial applications than for home heating.

For reliable, predictable, persistent, renewable energy, tidal power is a strong candidate. It is predictable rather than intermittent. With generating stations distributed around the country, there could be a constant feed into the grid.

However, while there was a definite, clear strategy for promoting offshore wind, with a Contract for Difference model, there has been no similar attempt to take tidal through the period when its costs are relatively high, to a point when it becomes usable and cost-effective. □

FST PODCASTS

Rebuilding the UK electricity grid – podcast with Dr Iliana Portugues, Futurist at Siemens Energy Global
www.foundation.org.uk/Podcasts/2022/Dr-Iliana-Portugues-Rebuilding-the-electricity-gri

Rebuilding the UK electricity grid – podcast with Nick Winser, Chairman, Energy Systems Catapult
www.foundation.org.uk/Podcasts/2022/Nick-Winser-Rebuildig-the-electricity-grid

VIEWPOINT

Sovereignty no longer resides just in secure territorial boundaries. Control of vital technologies is crucial if countries are to maintain their ability for independent action on a world stage.

The global race to achieve technology sovereignty

Hermann Hauser and Hazem Danny Nakib

Dr Hermann Hauser KBE is a physicist, innovator and entrepreneur, having co-founded the microchip design company ARM that is responsible for 95% of microprocessor designs worldwide. He has spent his career supporting cutting edge technologies that have revolutionised industries, from computing to synthetic biology, has invested in over 100 deep-tech companies and served as vice-chair of the European Innovation Council that is responsible for investing $12 billion into European start-ups. Hazem Danny Nakib is a financial and digital technology expert, philosopher and investor, having invested in over 30 technology businesses and started several incubators that have helped create over 200 research-based ventures. Hazem sits on the digital strategic advisory group of the UK national standards agency, BSI and is an Associate of the London School of Economics Systemic Risk Centre and visiting researcher at the University of Cambridge. The authors are currently writing a book together on Technology Sovereignty.

Imagine that Vice Admiral Eugene H Black III, commander of the US Sixth Fleet, suddenly requested something unpalatable of UK Prime Minister, with his fleet stationed in the English Channel. The Government and most people in the UK would regard this as a strange manifestation of the 'special relationship' between the USA and UK, as well as a flagrant violation of UK sovereignty.

Curiously, when former US Secretary of State Mike Pompeo requested the UK stop using Huawei 5G products, both governments understood that the USA indirectly controls the payment infrastructure of the City of London and that US chip and electronic design tool software is needed for the design of all UK electronic chips.

The UK acquiesced despite a thorough analysis by GCHQ, Britain's intelligence agency, concluding that Huawei products were safe to use in non-critical parts of the country's 5G infrastructure. Pompeo's request was no less forceful than having a US naval fleet moored in the Thames Estuary.

Sovereignty is conventionally considered as something that stems from the barrel of a gun or muzzle of a missile launcher. It is usually defined as the 'supreme authority in a territory' but is often thought of as being free from dependence on others. This classical account of sovereignty has to do with possessing the military might to either strong-arm other nations or deter them.

With the rise of technology, this classical view has changed faster than we could have imagined, in large part because of the importance of some technologies to our healthcare, economy, security and day-to-day lives. Many critical technologies make sure our hospitals, schools, modes of communication, financial system and food production continue to function unencumbered. Critical technologies have become so ubiquitous in our lives that the economy, society and our day-to-day lives would be disrupted without them.

This dependence was especially clear during the Covid 19 crisis, which showed how fragile supply chains around the world are and how no country was prepared with the PPE, ventilators or medicines their populations needed. The reliance of the world on Chinese manufacturing was unlike anything seen in a long time.

Technology sovereignty is the iconic issue of the 21st century, as countries race to control all critical technologies. Consider ARM, Britain's crown jewel, whose microprocessors power more than 95% of the world's smartphones with over 200 billion units sold. ARM was acquired by Japanese investor Softbank in 2016, and in 2020 US-based NVIDIA began a campaign to acquire them.

With the intervention of the US, UK, and EU competition authorities, the acquisition attempt was curbed because of its implications on technology sovereignty. If the sale had gone through, the US-based NVIDIA could prevent ARM from selling licences to NVIDIA competitors around the world and save the best licences for itself. US export controls would have meant the future of ARM's global footprint would be decided in the White House instead of No10.

Such dependencies in many areas of critical technologies would open Britain up to the risks of economic coercion by other nations through market-leading companies, coercion as effective as the military version of yesteryear but much more subtle. This has the power to disrupt our economy and create undesirable geopolitical leverage. We face the risk of becoming a technological colony of another nation if we do not have Technology Sovereignty in all, or at least some, critical technologies.

Key questions

Britain must ask itself three important questions:

1. Do we have the critical technologies ourselves?
2. If not, do we have access to these technologies from a number of independent countries to ensure a diversity of supply?
3. If still not, do we have guaranteed, unfettered, long term (i.e. greater than five years) access to monopoly or oligopoly suppliers of a single country (typically the USA or China)?

If Britain answers 'No' to these questions, it must do whatever it takes to build or secure capabilities in those technologies. One key question then becomes: which territories can be technologically sovereign in *all* critical technologies?

The world is already beginning to form into three Technology Sovereignty Circles, the USA, China, and Europe which represent the only nations or groups of nations capable of controlling access to all critical technologies. All other nations in the world will have to join one of these Technology Sovereignty Circles in order to access them and flourish in the 21st century.

To bolster its Technology Sovereignty, the USA has initiated a $100 billion technology independence programme and the EU is considering its own €100 billion fund. Meanwhile, China is the single largest investor in many areas of technology innovation including green technology, 5G and artificial intelligence.

To avoid becoming a technological backwater or technological colony, the UK must begin organising its affairs to build new capabilities in critical technologies. It can achieve this by scaling breakthrough companies at speed and securing the design, manufacturing and supply chains of critical technologies.

The UK does not have a problem in technology research with four out of the top ten global academic institutions based here. It also has no issue starting enough companies with a number of high-tech innovation clusters around the country. The Catapult centres that were established in 2010 (now over 40 in many areas of technology innovation and with further Government support) have also been a success in translating research to industry through commercial applications. The problem is not growing companies fast enough and big enough at home, a point recognised in the 2022 UK Digital Strategy published on 13 June[1].

Looking to the future, there are four key technologies that will become as ubiquitous as ARM microprocessors in smartphones and as important as PPE during the pandemic:

- Artificial Intelligence and machine learning;
- Quantum computing;
- Blockchain and smart contracts;
- Synthetic biology.

Britain has had a strong start in each of these areas with a number of research groups at different institutions and new cutting-edge companies emerging out of different clusters. To exploit this, Britain must establish a new minimum £5 billion p.a. technology sovereignty fund (less than 0.25% of annual GDP) that is focussed on making equity investments, matched by the private sector, in deep-tech companies in these four areas throughout the lifetime of the company. The ambition of this fund would be to turn these early stage deep-tech businesses into world-leading technology companies that are based and owned domestically.

Collaboration

At the same time, the UK cannot build technology sovereignty in all critical technologies alone. A new international process of supranational collaboration will ultimately need to emerge to counterbalance the ongoing and ever-accelerating US-China trade war that is concentrating access to these technologies into a new bipolar international order.

This new international process should be predicated on a new human right: one where all citizens have access to critical technologies, much like the right to life, property, and privacy. It would be founded on the basis of subscribing to shared common values in return for collective access to key technologies.

The UK can and should play an important role in engaging with partners to align on shared values. Think of a United Nations dedicated to spreading access to critical technologies and regulating the use of dual-purpose technologies, creating interoperable standards, reciprocal IP sharing arrangements, cross-border working arrangements in complex R&D, and supporting the growth of world-leading technology businesses between them. This is an approach to technology access focussed on value alignment instead of hegemony.

If a new international process is ultimately created, nations around the world will join and sign up to these shared values to avoid becoming a technological backwater or technological colony of the USA or China. This way forward provides the foundation for a new single Technology Sovereignty Circle that can scale globally. The US and China would then have no choice but to join or risk being left behind as they only represent one-fifth of the global population.

Through this dual internal and external approach, the UK has the opportunity to build Technology Sovereignty in a way that will ensure its citizens have access to the four technologies that will be the PPE of the future. It will also support the creation of world-leading companies to restock our Technology Sovereignty chest with new crown jewels, working with like-minded partners through shared values. □

To avoid becoming a technological backwater or technological colony, the UK must begin organising its affairs to build new capabilities in critical technologies.

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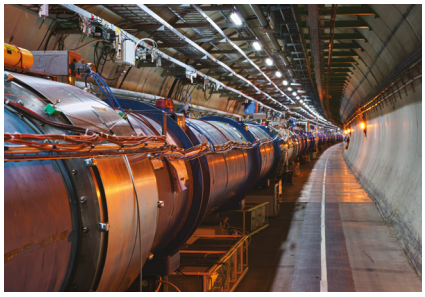
1. www.gov.uk/government/publications/uks-digital-strategy

The 2022 Foundation Future Leaders programme

On Wednesday 15 June, members of the 2022 cohort of the Foundation Future Leaders programme enjoyed a tour of Parliament and spoke to senior parliamentarians about the importance of science and innovation in their work. The Foundation Future Leaders programme brings together early- to mid-career professionals from Government, parliament, research and industry. The aim is to help them understand how other parts of the economy work and to enable them to network, building links that will help them engage across the whole economy in the course of their careers.



This year's Future Leaders programme includes a visit to CERN in September

Other activities in this year's programme include a visit to CERN in September where they will be able to see international collaboration in major science facilities, a visit to Loughborough university to explore how the research community contributes to UK science and innovation and visits to industrial facilities. One of the first events looked at the role of science and innovation industry. As in previous years, the cohort will organise a national conference for their peers in the autumn. ❑

RECENT PODCASTS AND BLOGS

Among the sections on the Foundation's website (**www.foundation.org.uk**) are regularly updated **podcasts** and **blogs**. These cover a wide range of topics touching on science, technology and innovation. Some, though not all, expand on the discussions that take place in the main Foundation meetings – these are detailed in the relevant sections of this issue. Some of the more recent postings are listed here.

RECENT PODCASTS

Dr Giles Campion and Professor Sir Gordon Duff
A regulatory regime for clinical trials

Dr Doug Parr UK
Energy Strategy

Dr Mina Golshan
Sizewell C and new nuclear power

Professor Paul Monks
Science Advice in BEIS

Ashita Anand
Heat Pumps

Professor James Wilsdon
Interdisciplinary Research

Dr Karen Salt
Trusted Research and Innovation

Prof Hugo de Burgh
Media and journalism in China

Vivienne Stern
UK/China University Collaboration

Dale Sanders
R&D Collaboration with China

RECENT BLOG POSTS

Dr Carlanne Stone
A personal message to science and technology future leaders

Chloe Davis
Will your energy bills go down with nuclear energy production?

Indro Mukerjee
Building the Future Economy

Jules Payne
Putting patients at the heart of early-phase clinical trials

Daniel Swerdlow
Improving clinical trial success by optimising patient selection – how can UK healthcare data resources help?

Sir Gordon Duff
A scientific superpower: harnessing the UK's early-phase research capabilities

Keyne Walker
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Dr Tom Dolan
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