fst journal

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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

COUNCIL AND TRUSTEES

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

The Foundation is sad to announce that The Earl of Selborne GBE FRS, former Chair and Vice President of the Foundation, died on 12 February. A note on his life and immense contribution to the work of the Foundation will be published in the next issue of the *Journal*.

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Lower carbon energy generation more competitive as costs fall

The levellised costs of electricity generation of low-carbon generation technologies are falling and are increasingly below the costs of conventional fossil fuel generation, according to the 2020 edition of the *Projected Costs of Generating Electricity* prepared by the OECD Nuclear Energy Agency (NEA) and the International Energy Agency (IEA).

With an analysis of 243 plants based on data from 24 countries, the report presents the plant-level costs of generating electricity for baseload electricity generated from fossil fuel, nuclear energy and a range of renewable technologies, such as wind and solar, hydro and biofuels.

Despite differences in regional, national and local conditions, the report finds that low-carbon generation is overall becoming increasingly cost competitive. Renewable energy costs have continued to decrease in recent years and the costs of wind and solar PV are now competitive with fossil fuel-based electricity generation in many countries.

Electricity from nuclear power plants is also expected to have lower costs in the near future. Due to cost reductions stemming from the lessons learnt from first-of-a-kind projects in several OECD countries, new nuclear power will remain the dispatchable low-carbon technology with the lowest expected costs in 2025.

The report also finds that prolonging the operation of existing nuclear power plants, known as long-term operation (LTO), is the most cost-effective source of low carbon electricity. Hydroelectric power can provide a similar contribution at comparable costs, but remains highly dependent on the natural endowments of individual countries.

www.iea.org/reports/projected-costs-of-generating-electricity-2020

New agency to fund high-risk research

The UK's next generation of pioneering inventors will be backed by a new independent scientific research agency, the Government has announced.

The new body, the Advanced Research & Invention Agency (ARIA), will be tasked with funding high-risk research that offers the chance of high rewards, supporting ground-breaking discoveries that could transform people's lives for the better.

The new agency, backed by £800 million in funding, will be independent of Government and led by some of the world's most able researchers. They will be empowered to use their knowledge and expertise to identify and back the most ambitious, cutting-edge areas of research and technology – helping to create highly skilled jobs across the country. It will be able to do so with flexibility and speed by looking at how to avoid unnecessary bureaucracy and experimenting with different funding models.

ARIA will be based on models that have proved successful in other countries, in particular the influential US Advanced Research Projects Agency (ARPA) model. This was instrumental in creating transformational technologies such as the internet and GPS, changing the way people live and work, while increasing productivity and growth. More recently, ARPA's successor, DARPA, was a vital pre-pandemic funder of mRNA vaccines and antibody therapies, leading to critical COVID therapies.

Research deal to boost AI in manufacturing

The Alan Turing Institute and the University of Sheffield Advanced Manufacturing Research Centre (AMRC) have signed an agreement to work together to identify opportunities for artificial intelligence (AI) adoption in manufacturing, accelerate research collaboration and boost skills development.

Researchers from the Turing and the AMRC hope to identify, and find solutions to, some of the grand challenges facing the manufacturing sector such as meeting increasing demand and the response to COVID-19.

The AMRC is a network of research and innovation centres working with manufacturing companies of all sizes from around the globe. It is part of the High Value Manufacturing (HVM) Catapult.

Mutual research areas of interest in the agreement between the Turing and the AMRC include:

- Uncertainty quantification;
- Human-centric design;
- Privacy-preserving technologies, including utility and application of synthetic data.

At the Turing, the collaboration will be led by the Institute's dynamic data-centric engineering research programme - a major £60 million research initiative funded by the Lloyd's Register Foundation. Looking forward, it is hoped the new collaboration will be the first of many in this research area.

www.turing.ac.uk

Satellite survey finds ice loss speeding up

The rate at which ice is disappearing across the planet is speeding up, according to new research funded by the Natural Environment Research Council.

The findings also reveal that the Earth lost 28 trillion tonnes of ice between 1994 and 2017 – equivalent to a sheet of ice 100 metres thick covering the whole of the UK. The research is the first of its kind to carry out a survey of global ice loss using satellite data.

Scientists led by the University of Leeds found that the rate of ice loss from the Earth has increased markedly within the past three decades, from 0.8 trillion tonnes per year in the 1990s to 1.3 trillion tonnes per year by 2017.

Ice melt across the globe raises sea levels, increases the risk of flooding to coastal communities, and threatens to wipe out natural habitats that wildlife depends on.

The findings of the research team, which includes the University of Edinburgh, University College London and data science specialists Earthwave, are published in European Geosciences Union's journal *The Cryosphere*.

https://tc.copernicus.org/articles/15/233/2021

GUEST EDITORIAL

With greater agreement on the challenge posed by climate change, what are the current pathways on the journey to a zero-carbon world?

The energy transition

Tony Meggs

Coming home from a period away offers the opportunity to reflect on what has changed. After a few years in major projects, I have recently returned to the field of energy and, while much of the landscape remains familiar, I am struck by how things have moved on.

Most importantly, the climate change 'debate' is largely over. This is obviously an over-simplification (there will always be opposing points of view) but the extent to which governments, corporations, stock markets, academics, activists and citizens broadly agree that climate change constitutes a real threat is striking. Of course, there are many perspectives about the scale of the threat, how it is best addressed and at what pace: indeed, some would even argue it is already too late. Yet there is a high degree of alignment that climate change is real and that it matters – and this consensus seems to be strengthening all the time.

Decarbonisation

Furthermore, remarkable progress is being made in the decarbonisation of the power sector, gas and renewables having steadily displaced coal as our primary energy source. In the UK, overall CO_2 emissions have dropped by around 40% since 1990 with much of that reduction occurring in the past 10 years or so. Indeed, emissions from the power sector have dropped by almost 75% over the period. Perhaps most striking is the speed at which costs for wind and solar power have come down; this has led to a more rapid build-up in renewables than anticipated just a few years ago. Although both wind and solar have benefited from advances in technology, the real gain has come from sheer manufacturing scale. As the number of wind turbines and solar panels grow exponentially, so costs are pushed down through standardisation and competition. Renewable power now outcompetes conventional power in many areas.

This is in stark contrast to the nuclear landscape, where multi-decade, largely bespoke projects strive to meet ever more demanding safety requirements, leading to a complete absence of learning effects. The result is that costs today are perhaps higher than ever. It is worth noting that nuclear fission creates around a million times more energy per unit of weight than a chemical reaction. Such vast sources of reliable zero-carbon baseload power should not be ignored as we build a carbon-free electricity-dominated future. Is it possible that small modular reactors could provide a route to cost efficiencies in the longer term, with similar cost benefits of standardisation and scale experienced with wind and solar?

The relative ease with which power is being decarbonised has created a strong case for the electrification of as much of the energy system as possible. This is already starting to happen in the transport sector, particularly for passenger vehicles and light goods vehicles. We are still at the early stages of this revolution – and much work will be needed to improve battery performance and drive down capital costs. As the major automotive companies electrify their fleets, electric vehicles are quickly becoming widely accepted in many parts of the world; the development of charging infrastructure will be the key enabler to widespread deployment.

The electrification of transportation represents a significant shift in a relatively short space of time. Not so long ago, biofuels were thought to represent the most likely solution to the decarbonisation of this sector. Much scientific work and many billions of dollars later, there have been no real technological breakthroughs in biofuels. While they will continue to play a role, it is likely to be much less prominent than once believed. This itself provides another lesson: the pathway to a carbon-free world is not straightforward or predictable; it is important to maintain an open mind, be experimental and recognise that not all experiments will succeed.

There are very significant issues associated with an increasingly electrified economy, particularly if the additional power supply is almost exclusively comprised of intermittent wind and solar. Variations in supply and demand on the grid are largely balanced out today through the use of gas-fired turbines. As the amount of intermittent supply grows, there is an increasing demand for load balancing, which will need to be zero carbon.

Many ideas are being pursued, but there is no clear pathway today. Solutions fall into two categories: smoothing out supply through storage; and smoothing out demand with smart metering driv-

Tony Meggs CB recently stepped down as Chairman of Crossrail Ltd, Europe's largest metro rail project. Prior to that, he was CEO of the UK Government's Infrastructure and Projects Authority, with oversight of HMG's largest and most complex projects and programmes and with responsibility for building project capability within Government. He has a background in energy, with many years in conventional oil and gas exploration. In his time at BP, he was responsible for technology development across the company with a focus on development of alternative energy opportunities including hydrogen.

The pathway to a carbon-free world is not straightforward or predictable; it is important to maintain an open mind, be experimental and recognise that not all experiments will succeed.

The energy system which underpins our lives is vast and complex. The transition away from fossil fuels will take decades – but we must do all we can to accelerate this transition; we should be ambitious while also realistic.

ing smart consumption. We have come to expect a completely reliable supply of power under all circumstances. However, considerable technology development and investment in infrastructure will be required to ensure that those expectations can continue to be met in the future.

The relatively recent change in CO_2 targets – from an 80% reduction by 2050 to zero CO_2 by 2050 –has had a galvanising effect on the clean energy discussion. In particular, it has dramatically increased focus on the 'hard to reach' sectors of the economy. Simply put, if one assumes 100% carbon-free power, accompanied by electrification of the car and van fleet (no mean feat, but conceivable), then attention turns to sectors where electricity is not necessarily the best solution, or even feasible in some cases. These sectors include space heating for buildings, long distance transport (including HGVs, ships and planes) and process heat for use in the manufacturing sector.

Hydrogen revival

This new focus has revived interest in alternative energy carriers – with hydrogen in particular experiencing one of its periodic revivals. Hydrogen has magical qualities: turn it into energy through burning it, or put in a fuel cell, and the only waste product is water. This could make it an attractive replacement for natural gas in space heating for example, and it could become the fuel of choice for long distance transport.

Hydrogen is widely used today in oil refining and fertiliser production; it is generally made from natural gas or, to lesser extent, coal and so the manufacturing process produces significant amounts of CO_2. Very low or carbon free hydrogen could be manufactured by adding Carbon Capture, Utilisation and Storage (CCUS) to the methane reforming process ('blue' hydrogen), or via electrolysis using carbon-free electricity ('green' hydrogen).

In addition to its potential role as an energy carrier, hydrogen offers promise as an energy storage medium. In particular, it is attracting a good deal of attention as a potential means of smoothing supply from intermittent sources: making and storing hydrogen when the wind blows (and prices are low) and converting the hydrogen back into electricity when demand (and prices) are high.

Despite its attractions, there are many challenges associated with the widespread use of hydrogen: in particular, manufacturing, storage, transmission and conversion to heat or power are inefficient for hydrogen, resulting in substantial losses along the chain. Costs of producing clean hydrogen are high – although no doubt production of electrolysers at scale would drive significant cost improvements, as we have seen with wind and solar.

Despite progress in creating widespread alignment around the reality of climate change and the need for action, despite the identification of feasible pathways to zero-carbon in developed economies, despite good progress in some countries such as the UK, even so we are not even close to the pace of change required to limit temperature increases to 2˚C or less above pre-industrial levels.

The energy system which underpins our lives is vast and complex; previous transitions have occurred, as for example when coal displaced wood to power the industrial revolution, but these took place over many decades. The transition away from fossil fuels will also take decades – but we must do all we can to accelerate this transition; we should be ambitious while also realistic.

Unlike previous transitions, which were driven in large part by the sound economics of increased energy density and the convenience of displacing energy sources, this transition will be driven much more by Government policy. Government support for wind and solar provided the initial incentives to kick start a global business that is now highly competitive without the need for subsidy. Much more of this kind of initiative will be required. Within a clear framework of emission reduction commitments, agile and innovative policies will be required to support the development of multiple efforts to reduce CO_2 emissions. No single approach will suffice to tackle such a vast challenge.

It will also be important to take account of the distributional impacts of climate policies. The move to zero carbon may have a disproportionate effect on certain sectors of the economy – it is essential to ensure that negative consequences are offset via other policy measures. Furthermore, in those many parts of the world which are currently suffering from extreme energy poverty, it is important to recognise that access to any form of energy may be more important than ensuring it is carbon free. Different parts of the world will move at different speeds, and richer countries may be under an obligation to over-achieve, ultimately going to negative emissions, in order to compensate for those least able to reduce carbon emissions in the short to medium term.

It is difficult to comprehend the scale of the challenge we face in rebuilding a global energy system that has evolved over many decades and that is deeply woven into the very fabric of our lives. It will be an immense challenge to meet the ambitious targets set over recent years and there will no doubt be many setbacks along the route. Yet we should not be overawed; remarkable progress has been made over the past few years and there is reason to be hopeful. ❐

CONTEXT

In July 2020, the Government published the *UK Research and Development Roadmap*, the first major policy document on research and development since the 2019 election. It covered a number of areas and confirmed the commitment to increase public R&D investment to £22 billion per year by 2024-25.

This document included a specific section on 'Levelling Up R&D Across the UK', as part of the Government's wider commitment to levelling up across the economy. The *Roadmap* detailed the existing investments in R&D in different regions of the UK and suggested actions to level up R&D investments.

A detailed analysis of the variation in R&D intensity across the UK, together with recommendations on levelling up, were included in a NESTA report published of May 2020 entitled *The Missing £4 Billion*. Previous Government policy has focussed on making public investments in R&D based on excellence regardless of geography. The UKRI *Strength in Places* fund is a recent exception, but with much lower sums than the NESTA report recommended.

On 7 October 2020, the Foundation brought together the UK Minister for Science, the co-author of the NESTA report and the Welsh Government Minister responsible for R&D to explore the issues. This event aimed to feed into further discussions within the UK and devolved governments on place-based R&D investment. A video recording, the presentations and speaker audio from the event are available on the FST website.

A new social contract for science, research and innovation

Amanda Solloway

SUMMARY

- Science, research and innovation will help us build a better world
- For many people, the R&D environment is unfamiliar
- Challenges and opportunities vary across different parts of the country
- We need to renew the social contract for research
- We need a change in mindset.

I do not have a degree, having left school after my A-levels. Subsequently, my career has been spent in a variety of businesses and, latterly, politics. So I am somewhat unique as far as science ministers go.

Science and innovation matter a great deal to me, they are very close to my heart. I have never shied away from innovating and I have tried to foster creativity and innovation everywhere I have worked. I have always had a deep appreciation of how crucial science and innovation are to our future as a country.

Science, research and innovation will help us build a better world and will impact on everybody. We can see this in ways that we already take for granted. I remember my first-ever calculator – a big advance from the slide rule that I used for my O levels! Yet my granddaughter will grow up surrounded by technological wonders that I, as a child, could only find in the science fiction of Isaac Asimov.

Science and innovation will also help us build a more sustainable – and safer – world. It can also give us a fairer world.

Yet, it is important not to forget that for many people, our R&D world is an unfamiliar place, a totally different walk of life. It is perceived to enrich the major cities in London and the South East, while leaving little for the rest of the country.

I believe every person in my constituency, and throughout the country, should benefit from the advances in science and technology. However, the challenges and opportunities in Derby are very different from those in Oxford, Cambridge or London. Scientists need to recognise that and gain a better understanding of the diversity of people outside this profession.

A social contract

Put simply, we need to renew the social contract for research. That means making it easier to translate the results of our scientific and research system into better jobs, better products, better services and a better quality of life for more people, all over the UK.

To achieve that, we will need to work together to foster a rich and vibrant ecosystem of innovation, connecting research and industry, academics and

Amanda Solloway was appointed Parliamentary Under Secretary of State at the Department for Business, Energy and Industrial Strategy (BEIS) in February 2020 and is the Minister for Science, Research and Innovation. She has been the Member of Parliament for Derby North since 2019, having also represented the constituency between 2015-2017. During that first period, she was Parliamentary Private Secretary (PPS) to the Secretary of State for International Development and sat on the committee for Human Rights and then the committee for Business, Energy and Industrial Strategy.

Anti-vaxxer sentiment has existed since Edward Jenner first developed the smallpox vaccine in the 18th century.

WELLCOME IMAGE

policymakers, and institutions and civil society.

We will need our immense capacity for creating new knowledge to fuel our recovery, building our understanding of place into decision-making at all levels, and attracting the private investment to deliver growth.

We will also need to develop models of training and skills that allow more people to benefit from a more vibrant knowledge economy, and to participate in it.

In addition, there needs to be a deepening of the interactions between science and society. For me, that means seizing every available opportunity to inspire even more people, building excitement about the amazing things that we are doing.

Yet, in this age of flat-earthers and anti-vaxxers, it is crucial to create confidence in science and research, building mutual trust between those doing research and those affected by it.

Exclusive, not narrow

Now, there are some people involved in science who remain deeply committed to notions of exclusivity. There is, of course, a real value in wanting to be the best and we must not ever undermine that: indeed, we must strengthen it.

Obsessing over narrow indicators of success, though, can mean that funding and assessment systems become disconnected from the diverse needs of our nation. That risks neglecting the contributions that so many people already make to our R&D sector: those adopting and using technologies, those inventing them, as well as the local leaders and institutions around the UK who have the networks and insights to bring our R&D system to life.

It is absolutely vital that we now start to harness the potential of more people and bring them into the R&D system. We need to involve different sorts of people from all sorts of places. We will need to collaborate across boundaries and borders to find the best solutions. There need to be better interfaces between Government, funders, institutions and local leaders.

Put simply, we all need a change in mindset.

Levelling up

There is a great deal to be done in order to make a success of levelling up. There have to be proper, informed debates about the best ways to achieve our aims and the right role for R&D investment – that is why I established a Place Advisory Group to help develop our Place Strategy for R&D.

Levelling up is about much more than straight economics. It concerns how science, research and innovation can help us to become a more inclusive economy, and a less divided country.

Yet levelling up is about much more than straight economics, or funding models, or indeed winners and losers. It concerns how science, research and innovation can help us to become a more inclusive economy, and a less divided country. It involves equality of opportunity while embracing diversity and difference. It will mean strengthening connections across our country so that more people and places can benefit from the UK's status as a 'science superpower'. It is also about building trust and respect.

In short, the levelling up agenda is concerned with building the kind of country we all want. ☐

Correcting for regional imbalance

Richard Jones

SUMMARY

- Economic productivity varies significantly across the UK
- There is a correlation between GDA per head and R&D spending
- To level up, substantial additional funding needs to be allocated to some regions
- Regionally, there are imbalances between public and private sector funding levels
- More emphasis is needed on translational research.

Professor Richard Jones FRS is Chair of Materials Physics and Innovation Policy at the University of Manchester. He is an experimental soft matter physicist. In 2006, he was elected a Fellow of the Royal Society in recognition of his work in the field of polymers and biopolymers at surfaces and interfaces. He was Pro-Vice-Chancellor for Research and Innovation at Sheffield from 2009 to 2016, was a member of EPSRC Council from 2013-2018, and chaired Research England's Technical Advisory Group for the Knowledge Exchange Framework.

The UK is a divided nation. In terms of economic productivity, East Anglia, London and the South East are prosperous, but other parts of the UK are more comparable to East Germany, Southern Italy or Portugal. We have parts of the country that are economically successful, with a transfer union to make sure public services in the rest of the country benefit from London and the South East (as it should). The aim of levelling up should be to improve the economic performance of those places that do not do as well as they could, so that there is a more level spread in economic performance and that kind of resource transfer between regions is less necessary.

R&D is astonishingly concentrated. London, Oxford and Cambridge and their sub-regions account for 46% of all spending in the UK. These places are very research-intensive, very successful, knowledge-based economies, but it means there are great swathes of the country where people do not encounter scientists – and that creates a double problem. Those places may be underperforming because they are not getting the benefit of innovation, but in addition, people just do not come into contact with science and people in scientific or technical jobs.

The rich get richer R&D

While R&D is not the only determinant of performance and productivity, there is a correlation between GDA per head and R&D spending. The linkages are complicated, but if places are more economically productive, that translates into better jobs, better wages and better quality of life in all sorts of ways. R&D is one of the tools that will help places become more productive, yet it is concentrated in the places that already perform very well.

In London, the South East and East Anglia, about £220 per person per year is spent on public R&D. Yet the rest of the country – the North, the Midlands, South West, Wales and Northern Ireland – receives less than half of that.

To redress the balance and level up, the extra annual spending needed can be seen in Figure 1 (Scotland already receives about as much as the South East). That gives a total of about £4.2 billion.

To put that number in context: UKRI's budget last year was £7 billion, so this would represent a large number compared to the existing science budget. However, the Government has committed to increasing this to £22 billion by 2025. So, while £4.2 billion is a big number, it is not a ridiculous number in the context of the Government's intentions.

It is instructive to look at the investment in innovation made by Regional Development Agencies (RDAs) more than a decade ago. Total spending in the period 2005-8 was £323 million. The Labour Government in the 2000s tried to give money through the RDAs, but the sums were too small to make a material difference to regional economic performance.

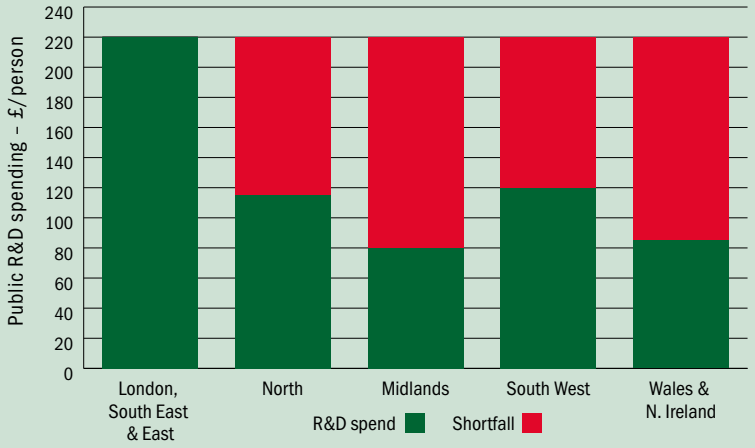
Then there is the difference between private sector and public sector spending. Figure 2 shows, on the x-axis, how much the public sector spends. The other axis shows how much the private sector puts in. Roughly speaking, over the country as a whole the private sector puts in about twice as much as the public sector.

Places like East Anglia in the top right quadrant have a very large public sector spend on R&D, but then the private sector puts in even more. These are great places, these are the kinds of economies we want to emulate. Cambridge is an outstanding knowledge economy and we would like to see other places like that. Levelling up should not involve taking money away from Oxford and Cambridge, it is concerned with emulating that success elsewhere.

In London and Scotland (bottom right), the public sector puts in a great deal more than the business sector. So, here the focus needs to be on

R&D is one of the tools that will help places become more productive, yet it is concentrated in the places that already perform very well.

Figure 1. Levelling up – the scale of the problem



Extra annual revenue spending required to "level up" per capita spending to London/South East/East average.

North - £1.6 billion
Midlands - £1.4 billion
Southwest - £570 million
Wales and Northern Ireland – £660 million **Total: £4.2 billion**

UKRI budget:	£7 billion /pa
Total public spending on R&D by 2025 promised in March budget:	£22 billion/pa
Total spending on innovation by the English RDAs 2005-2008:	£323 million

driving up business R&D, perhaps through more translational research.

The top left quadrant includes areas which have high private sector investment in R&D, but the public sector is not doing the same. Here, the market is providing signals about the sectors to be supported and there is a really strong case for the public sector to follow those signals, to enhance innovation economies that are already quite strong.

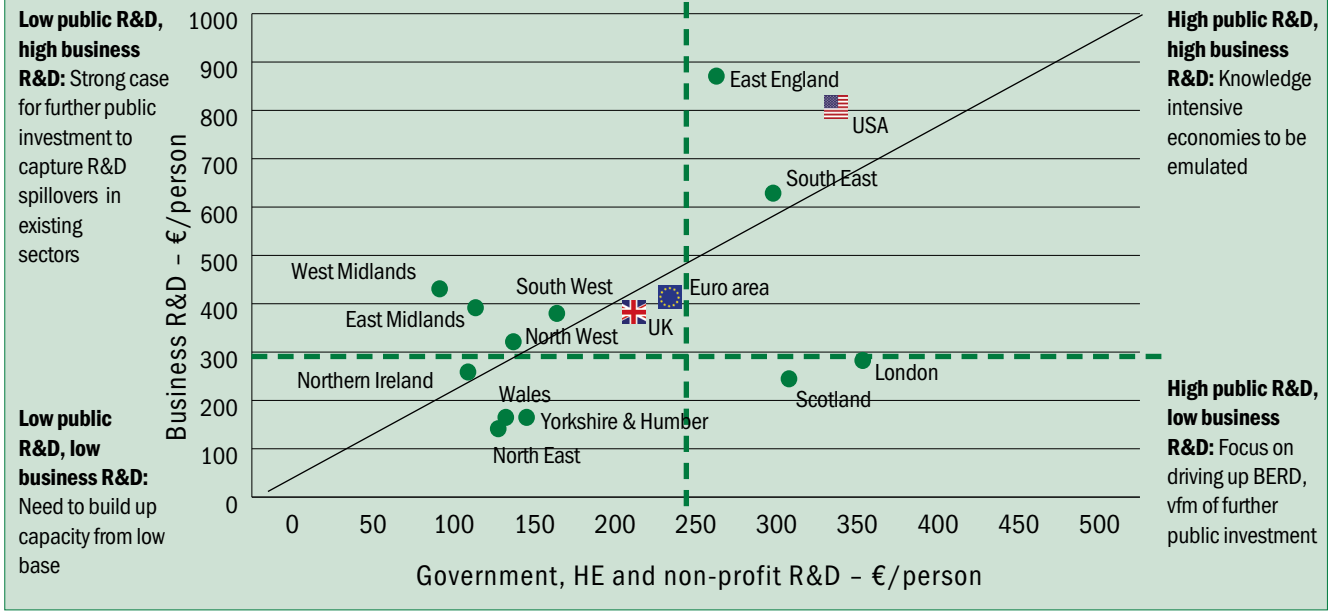
Finally, there are areas that have relatively weak innovation economies both in the public sector and in the private sector (bottom left). Here, there is a need to build capacity and that depends on making good choices on investment. Northern Ireland is a good example of what can be done. Collaboration between the universities, the city of Belfast, the devolved administration and business has created a cyber security and digital technology cluster, leading to a significant increase in business R&D. In Wales, a compound semi-conductor cluster is growing in South East Wales. That has been supported by the Welsh government over a decade or more.

We need to devolve R&D funding to the nations, the cities and the regions of the UK. Local knowledge can help to decide the right priorities for those areas. Work must continue on building the capacity to make good decisions about innovation. This is less of a problem in the devolved nations because that capacity largely does exist: however, in the English regions and cities, that needs more work as devolution unfolds.

We need new R&D institutions. There is a consensus that the UK needs to put more emphasis on translational research and there are some interesting ideas about using innovation districts and manufacturing parks to support and help grow knowledge-intensive business clusters.

Finally, a culture change within the UKRI funding agency is desirable. There should be formal representation of the nation's regions and there need to be more place-based funding instruments to build capacity across the whole nation, like UKRI's Strength in Places Fund. ❐

Figure 2. Different places, different a pproaches



Success depends on involving all the key actors

Ken Skates

SUMMARY

- The UK today is the most regionally unbalanced economy in Western Europe
- A successful 'levelling up' strategy has to fully involve the devolved governments
- As a place to carry out research and to innovate, Wales has a lot to offer
- Wales needs the scale to compete more fairly on the UK stage
- The Welsh Government is best placed to understand and respond to opportunities in Wales.

The Welsh Government has been discussing the need for levelling up for many years, so I am very supportive of any attempt by the UK Government to do so. There are a number of areas – from rail infrastructure to R&D – where patterns of investment are uneven and unfair. The stark fact is that the UK today remains the most regionally unbalanced economy in Western Europe, according to OECD figures.

It is not just that policy has not worked: we are, in fact, going backwards. The *Financial Times* recently reported that regional inequality in the UK has now returned to the same level as 1900.

That is why any attempt by the UK Government has to be more than fine words. The Welsh Government's view is that genuine levelling up cannot simply mean a sprinkling of new projects decided in London: it has to be a strategic approach promoting growth in all parts of the UK.

Nor can it just be about equality of access – the ability to 'bid in' to new funding sources. It must be based around outcomes and a genuine attempt to narrow the investment gap between Wales and the rest of the UK. This requires a degree of positive discrimination to counter the inbuilt advantages of areas already strong.

Any successful levelling up approach has to fully engage devolved governments in its design and governance. Not to involve the devolved governments undermines devolution and risks destabilising the union itself.

The inequalities really do matter. As the Industrial Strategy Council and recent Nesta reports concluded, they prevent the UK economy from realising its full potential. They blight people's life chances. They create a widespread sense of alienation and frustration, particularly here in Wales.

The future prosperity and stability of the UK depend on all parts of the union being able to contribute to an innovative and productive economy. It cannot be right that over half of UK R&D spending takes place in London and the South East of England. It cannot be right that Wales receives just 2% of UK R&D investment, despite making up 5% of the population.

No level playing field

Historically this has been justified on the grounds that R&D funding is allocated on the basis of 'excellence' or 'competition'. But the playing field is not level: the regions which dominate R&D spending have been favoured by public policy and geographical bias for decades.

To give just one example (and it is certainly not the only one), there was a debate about the location of the Diamond Light Source, the UK national synchrotron science facility, some two decades ago. A strong case was made for Aberystwyth, where the university had expertise in synchrotron radiation and access to EU Objective 1 funding.

Sheffield, another Objective 1 area, was also suggested. So was the North West of England, where there was an existing synchrotron at Daresbury in Cheshire. Diamond could have been a real driver of economic growth in West Wales or South Yorkshire or the North West. Instead, it ended up near Oxford, a place in no particular need of 'levelling up'.

As a place to carry out research, and to innovate, Wales has a lot to offer. More than three-quarters of the work Welsh universities submitted to the Research Excellence Framework in 2014 was assessed as world-leading or internationally excellent. Independent reports by Elsevi-

Ken Skates MS is Minister for Economy, Transport and North Wales in the Welsh Government. He was elected to the Senedd in 2011 for the Clwyd South constituency. In June 2013, Ken was appointed Deputy Minister for Skills and Technology, then Deputy Minister for Culture, Sport and Tourism in September 2014. In May 2016 he was appointed Cabinet Secretary for Economy and Infrastructure (now titled Minister for Economy, Transport and North Wales).

Any successful levelling up approach has to fully engage devolved governments in its design and governance.

DIAMOND LIGHTSOURCE

A strong case was made to locate the Diamond Light Source facility at Aberystwyth, where the university had expertise in synchrotron radiation and access to EU Objective 1 funding. Instead the facility was built in Oxford.

er showed that Wales 'punches above its weight' scientifically. We are also doing well in the commercial application of research. The UK Innovation Survey revealed that more Welsh companies are 'innovation active' than their peers in Scotland or Northern Ireland.

A question of scale

What we really need is the scale to compete more fairly on the UK stage. Our research base does not have the size and scope to deliver its full potential for our economy and society. While the Welsh Government has invested heavily (through, for example, our Sêr Cymru – 'Stars of Wales' – programme to attract new scientific talent), we had to secure a large share of our research and innovation funding from EU Structural Funds. EU funding has made a major contribution to increasing the volume, quality and impact of research in Wales over the past 20 years.

Before the EU referendum, the Leave campaign – in which the Prime Minister and many of his Cabinet colleagues were prominent figures – promised that Wales would not be a penny worse off as a result of Brexit. Now the UK Government must make good on that promise.

The Leave campaign promised that Wales would not be a penny worse off as a result of Brexit. Now the UK Government must make good on that.

We want to see a clear commitment to replace the Structural Funds we are losing, on a pound-for-pound basis. Otherwise, R&D in Wales will not level up – more like be sent back to square one!

The importance of harnessing devolution

Then there is the question of who should decide how the money is spent. A recent Nesta report proposes that much more R&D funding should be devolved to the UK's nations, regions and cities. We agree with the principle: the Welsh Government is best placed to understand and respond quickly to opportunities here in Wales. Whitehall does not always know best!

R&D investment can only be successful if it is part of a wider policy agenda – in our case our Economic Action Plan. Even more importantly, the people of Wales expect their devolved government to have a strong voice in the decisions that affect them. As our First Minister has said, the UK will only continue to survive if it is a genuine partnership between its peoples and nations.

We welcome a greater focus on 'place' in R&D funding. We want to see a more equitable balance across the UK's nations and regions. We want to develop the capacity to carry out research and innovation at scale in Wales, not just for our own benefit, but to make our full contribution to the UK's long-term growth and prosperity.

We stand ready to be a full and constructive partner in the delivery of this agenda. ❐

The debate

After the formal presentations, the speakers came together as a panel to respond to questions from the audience on R&D, the Catapults, the Shared Prosperity Fund and the role of Chief Scientific Advisers.

The speakers were asked whether the priority should be on the 'D' of Development rather than the 'R' of Research. The RoadMap is very ambitious for both R and for D. However, in international comparisons the UK is weaker in D than in R.

The Innovation Expert Group is now meeting regularly with the UK Science Minister. In the context of a rising budget, more translation research makes sense, as evidenced by the Advanced Manufacturing Research Centre and the Compound Semiconductor in Wales, both of which have been successful and attracted significant commercial investment.

The panel agreed that Catapults could be used as an instrument for levelling up. The network should be expanded, with greater connectivity between Catapults themselves and also between Catapults and the research base. Further 'spokes' of Catapults to reach more remote areas of excellence would be beneficial.

It was noted that 4 out of 5 peer-reviewed research proposals were unfunded, and previous governments had secured flat cash settlements for science during the last recession. The panel noted the commitment to increasing the budget for R&D to £22 billion by 2025. They also noted that as well as research funding and structural funds, levelling up needed to take place in other areas such as transport infrastructure.

The Green Book

The review of the Government's Green Book was welcomed. When asked about what contribution the upcoming Shared Prosperity Fund (to be operated by MHCLG) could make to R&D, it was noted the importance the EU structural funds had made to building R&D capacity in weaker economic regions. It was crucial that this was also seen as important in the SPF, and discussions were ongoing between BEIS and MHCLG.

It was noted that the SPF could militate against the devolution settlement unless devolved administrations were given both the same level of funding and the same control of spending decisions they had with EU Structural Funds.

The panel were asked whether cities should appoint Chief Scientific Advisers, and agreed that cities and some regions did need more powerful structures to help identify priorities and also link in with UK national decision-making. Chief Scientific Advisers could be one mechanism which would help. □

FURTHER INFORMATION

The Missing £4 Billon – NESTA, May 2020
www.nesta.org.uk/report/the-missing-4-billion

UK Research and Development Roadmap – UK Government, July 2020
www.gov.uk/government/publications/uk-research-and-development-roadmap

Prosperity for All: Economic Action Plan – Welsh Government, March 2019
https://gov.wales/sites/default/files/publications/2019-02/prosperity-for-all-economic-action-plan.pdf

R&D Place Advisory Group – UK Government
www.gov.uk/government/groups/rd-place-advisory-group

The Power of Place – Campaign for Science and Engineering, May 2020
www.sciencecampaign.org.uk/resource/placereport.html

More D! – A more development-focussed strategy for paving the way to impact – AIRTO, March 2020
www.airto.co.uk/wp-content/uploads/2020/03/AIRTO-More-D-Position-Statement-31-MARCH-2020-web.pdf

Speed to Scale Region programme – West Midlands
www.ssr-wm.org.uk

- FST blogs and podcasts

Levelling up innovation and research investment for prosperity across all UK nations and regions – blog by Professor Peter Halligan, Chief Scientific Advisor, Welsh Government
www.foundation.org.uk/Blog/2020/Levelling-up-innovation-and-research-investment-fo

R&D RoadMap and levelling up – podcast with Professor Richard Jones
www.foundation.org.uk/Podcasts/2020/Professor-Richard-Jones-R-D-Roadmap-and-Levelling

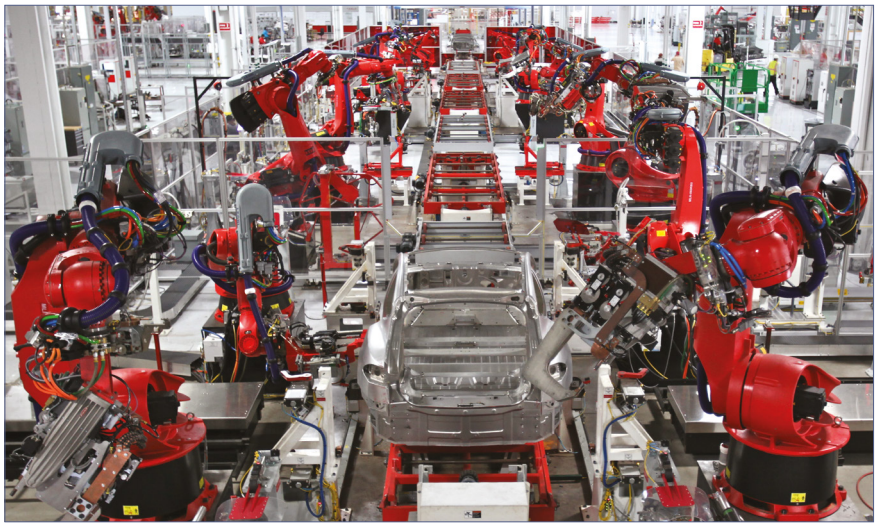
R&D RoadMap and implications for Scotland – podcast with Dr Stuart Fancey
www.foundation.org.uk/Podcasts/2020/Dr-Stuart-Fancey-The-R-D-Roadmap-and-implications

R&D in Northern Ireland – podcast with Professor Gerry McKenna
www.foundation.org.uk/Podcasts/2020/Professor-Gerry-McKenna-R-D-in-Northern-Ireland

A joint webinar on 21 October 2020 between the Foundation and Resilience First looked at the need to build resilient skills as we emerge from the Covid-19 pandemic.

Building resilience in a changing world

FST Chair Lord Willetts opened the webinar by setting out three issues. The first was the extent to which the Covid-19 virus was driving structural change in the economy. Some trends are already visible, but others are hard to predict – hence the need for resilient skills. Second, what were the resilient skills needed? Literacy and numeracy were as vital as ever, and we know that digital skills are increasingly important, but what else? The third element was the policy implications flowing from this. The Prime Minister has announced action on skills including the Lifetime Skills Guarantee. What other levers are available?



STEVEJURVETSON (CC BY 2.0)

Electric car manufacturing will create new jobs and require new skills

Ben Fletcher, Executive Director of Policy and Engagement at MakeUK, set out some of the challenges affecting UK manufacturing. There has been a renaissance in manufacturing over the past 20 years. The UK is in the global top 10 for manufacturing (though public perception is that it is much lower). Manufacturing represents 12% of UK economy but around 50% of exports, and the UK is one of the world's best countries in using just-in-time logistics. However, skills development has not kept up – and for manufacturers, skills remains the priority issue.

The UK university sector produces graduates with excellent engineering skills, including in digital engineering, but there is a lack of people in the medium-skilled technical level.

Apprenticeships

Apprenticeships should be a key part of the solution. Indeed, there has been an increased interest in apprenticeships over the past few months, but because of the pandemic firms do not have the money to take them on. In MakeUK's own apprenticeship scheme, numbers have fallen below 100 due to financial pressures on firms.

Fletcher argued that the Government should make reforms to the Apprenticeship Levy, to allow greater flexibility in the way business can use the funds. Covid could be a real driver to increase digital skills, but where people already have technical skills in other areas and want to upskill, they may not qualify for the support recently announced by the Government. More flexibility is crucial.

There has sadly been an increase in redundancies in manufacturing, particularly among older workers trained in skills that are becoming less relevant to firms. As manufacturing is a larger part of the economy in UK regions where the Government is aiming to level up, a regional approach to support may be needed. Apprenticeships are also more expensive in engineering and manufacturing.

Austen Okonweze, Deputy Director, Engagement & Planning, Industrial Strategy at BEIS (the Department of Business, Energy & Industrial Strategy) highlighted the importance of education and skills when addressing productivity challenges. Some 20% of the rise in productivity over the previous 15 years is attributable to improvements in the quality of the workforce.

The Covid pandemic has had a major impact on the economy and the labour market. Some particularly badly hit sectors may not recover their pre-crisis baselines, so the post-Covid economy will look different. The young, the lower paid and women are most likely to be seriously affected.

Apart from Covid, other global trends are transforming the workplace. Automation means a change in the tasks people perform. The transition to net zero may create jobs in new sectors, such as electric vehicles. The digital transformation of business was already underway before Covid. An ageing population means more people retraining later in life to change careers. In the UK, EU exit is a further factor will have an influence.

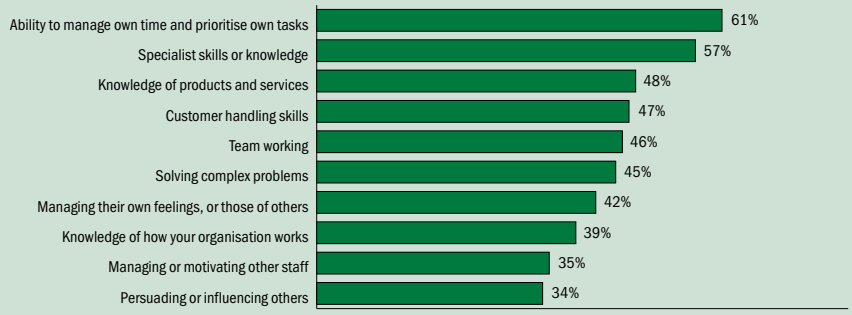
Skills shortages are costing UK organisations more than £4 billion per year, and a lack of access to skills is

reported by UK firms as the primary threat to competitiveness. STEM skills are in particular demand, with nine in 10 STEM businesses finding it difficult to get the skilled people they need. Digital skills are now core: what were previously seen as advanced skills are now regarded as basic capabilities.

The consequence is that everyone needs opportunities to learn new skills. More than 80% of the 2030 workforce is already in the labour market. The focus, therefore, needs to switch to lifelong learning, retraining and upskilling, enabling people to be adaptable to changes and to take advantage of new opportunities. This needs to be a collaborative effort between Government, employers and individuals.

The Prime Minister has announced the Lifetimes Skills Guarantee and has spoken about the necessity of investing in skills, the need to level up Further and Higher Education, and the importance of reskilling and upskilling.

Figure 1: Top 10 skills identified as needing improvement among existing staff



Source: Employers Skills Survey, England 2019

The UK is finding it a challenge to nurture the skills that organisations need

Human skills

Lizzie Crowley, Skills Adviser, Chartered Institute of Personnel & Development said that while the world of work in 2030 would look very different from today, it was very difficult to predict what the jobs of the future would look like. Instead, CIPD was focussing on the core skills that would be needed. The majority of these were 'human' skills, and the 2018 *Future of Jobs Survey* from the World Economic Forum listed analytical thinking, creativity, active learning, problem-solving, leadership, reasoning and emotional intelligence. A report by Nesta and Pearsons used a different methodology but came up with similar results.

Despite the importance of these skills, it has been true for many years that both existing and new employees are struggling to develop and apply them. This is true for all levels and age groups within organisations. Human skills make up seven out of the top 10 gaps reported (see Figure 1). This is not a new problem. Identified by the CBI in 1989, the UK has failed to make much headway in addressing the problem.

What can be done? These skills need to be embedded throughout the education system, with opportunities to build these skills across the curriculum, as well as the ability to engage with employers while still in education. Employers need to allow their employees to develop these skills throughout their career. These skills can be learned, and coaching and mentoring can be effective. Better job design can also allow staff to use and develop such skills, with support from their managers.

> These skills need to be embedded throughout the education system, with opportunities to engage with employers while still in education.

One problem is a lack of a common and agreed language to describe these skills and a common framework to measure and assess them. The Essential Skills Taskforce have been working to address this. This has led to a revised Skills Builder Framework which has now been launched and is already being used by employers.

The debate

The panel noted that the pressures of exams and the National Curriculum make it difficult for firms to come into schools to discuss work. Financial incentives mean it is better for schools to keep students on into the sixth form rather than encourage them to take up apprenticeships. The Government has introduced T-Levels, but many employers are still unaware of them, and there are challenges.

The Apprenticeship Levy has led to a decrease in apprenticeships in manufacturing, as the funding is less than the cost of the apprenticeship in that sector. More flexibility in what the Levy funds could be spent on would be helpful.

Given the massive changes to the economy from Covid and other events, the Government will be refreshing the Industrial Strategy, and will consider whether sector deals could be used to drive more employer investment in skills – working in consultation with employers.

The panel noted the lack of quality careers advice and guidance for students. A better system would enable the UK to encourage students to develop the skills that were needed. The Lifetime Skills Guarantee needs to be operationalised quickly. It was noted that funding for adult learning has been cut by 40% since the last recession. Employer funding of training is also declining. The UK could learn from the Australian Pioneer Fund.

It was noted that there had been a lack of policy stability and long-term vision for skills. There is a need for a national skills strategy. The Further Education White Paper could provide a long-term vision for the sector.

Audio and video files of all the speeches can be found on the Foundation website. □

Resilience First is a membership organisation, led and funded by business, with the mission to improve urban resilience for business communities in the UK and beyond. **www.resiliencefirst.org**

CONTEXT

UK Research and Innovation (UKRI) was established following the *Higher Education and Research Act* 2017 and came into being in April 2018. It brings together the seven UK Research Councils, plus Innovate UK and Research England. The Foundation discussed the creation of UKRI and its initial priorities in its meeting on 28 February 2018[1] (see *FST Journal* Volume 22 Issue 3) with the first Chief Executive of UKRI, Professor Sir Mark Walport FRS.

In June 2020, Sir Mark retired and was replaced as Chief Executive by Professor Dame Ottoline Leyser DBE FRS. This seemed an appropriate time to revisit UKRI, and consider its priorities going forward, including consideration of the challenges posed by Brexit and coronavirus.

A meeting of the Foundation was held on 2 November 2020, bringing together Dame Ottoline, a senior academic and an expert on innovation, to explore how UKRI should develop. All the presentations and audio from the event can be accessed at: www.foundation.org.uk/Events/2020/Future-Priorities-for-UKRI.

1. www.foundation.org.uk/Events/2018/UKRI-leaves-the-starting-blocks-the-management-of

Creating a flexible, inter-connected and effective system

Ottoline Leyser

Professor Dame Ottoline Leyser DBE FRS is the Chief Executive of UK Research and Innovation (UKRI) and Regius Professor of Botany at the University of Cambridge. Prior to this, Ottoline Leyser 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

- UKRI is the largest public funder of research and innovation in the UK
- The research and innovation landscape makes up a broad and inter-connected system
- A strictly linear conception of research and innovation is unhelpful
- The system should incentivise many different people to enter and engage with it
- UKRI's focus is to ensure the whole system is healthy and sustainable.

UK Research and Innovation is the largest public funder of research and innovation in the UK. It is less than three years old and brings together the seven Research Councils, Innovate UK (the country's innovation agency) and Research England. It has an annual budget of more than £8 billion.

The constituent organisations have deep expertise and understanding of their disciplines. Bringing all of that knowledge and expertise together creates extraordinary opportunities to capture synergies and really to get the most out of our research and innovation system.

We build partnerships across academia, businesses, Government and a whole different range of public sector bodies, the third sector and, crucially, international organisations. Our role is to look at the research and innovation system as a whole and to use our understanding and insight to build a holistic system that genuinely works to deliver for the UK and its international partners.

That is captured succinctly in our vision and mission, which is to build an outstanding, creative, dynamic research and innovation system for the UK. It has to be truly inclusive, where everyone can participate and everyone can benefit.

While we are a major player in this system, we are definitely not all of it, though we do have a unique opportunity to steward it and influence it. There are a variety of levers to achieve that. With money we can invest in people, ideas and infrastructures, building a portfolio that serves that whole system. We can convene and we can catalyse. We can engage with a range of other communities to understand how different people want to contribute to, and benefit from, research and innovation in the UK. And of course we can incentivise and influence the ways the system works.

I think about research and innovation as a system because unless it is approached in a connected, joined-up way, we will not achieve the best results. A key problem is the tendency to think about research and innovation as a linear process where there are discoveries at one end and then a translational process converts them into products at the other. We invest, for example, in discovery and we currently measure discovery primarily through publications; we invest in products and we measure products by GDP or patents. Thinking solely in this way misses crucial elements.

Linearity is an unhelpful simplification

SHUTTERSTOCK/ GORODENKOFF

The popular image of the lone researcher in their lab can be misleading – the reality is much broader

which leads to misunderstandings. There is a well-known narrative in this country that we are extraordinarily good at the discovery end and there is a 'valley of death' between that and the product end. The 'valley of death' tends to refer to missing money along that linear, transitional pathway.

However, an effective research and innovation system is not a linear pathway between one end and the other. It is more like an iceberg where what we can see is just the visible tip of the structure. We need to think much more holistically about who is in the system and what is needed to make it work effectively. This is where UKRI needs to focus. We need to think not only about discoveries and products but also crucially about connectivity.

Support systems

There is a popular image of lone researchers in their labs or libraries coming up with new ideas and insights. The reality is much broader and we have to consider who comes into the system from schools, for example, and from Further Education colleges, and we have to take into account all the support systems they need – the IT systems, the administrative staff, project leaders, librarians, archivists.

Within the system there are Public Sector Research Establishments, there are small companies, big companies and a whole ecosystem of institutions that are delivering research and innovation. UKRI needs to connect these and, in the context of that discovery/product relationship to which I alluded, people and ideas have to move freely through the system. In fact, it is through this movement of people that the joining-up happens.

The system should incentivise all these different people to enter and move through on flexible career paths. Current structures do not always facilitate this, at least not nearly enough.

The UK R&D Roadmap sets out very clearly the idea of an inter-connected system with an ambition to drive our research and development forward by bringing in a much wider range of people and aims to connect the discovery/research phase more closely with innovation and productivity. Through that combination, it aims to drive levelling up in R&D across the UK.

To create a truly inclusive system, to which everyone can contribute and from which everyone benefits, world-leading infrastructures and institutions are needed to bring the right people together and to connect the UK system globally. The role of UKRI, in my view, is to ensure the whole system is healthy and sustainable and has a really vibrant and creative culture – particularly in a post-COVID world where we need to 'build back better'. ❐

People and ideas have to move freely through the system. In fact, it is through this movement of people that the joining-up happens.

The real value of research

David Paterson

Professor David Paterson is Head of the Department of Physiology, Anatomy & Genetics, University of Oxford and Fellow of Merton College, Oxford. He is the current President of The Physiological Society and was Editor-in-Chief of The Journal of Physiology. From 2008-16 he was Associate Head then Deputy Head (Vice Dean) of the Division of Medical Sciences and a member of the national Research Assessment Exercise (RAE 2008) and Research Excellence Framework (REF 2014) panels.

SUMMARY

- The UK needs to become better at bringing together the whole research landscape
- Discovery science and mission science are not mutually exclusive
- There is pressure on the QR funding model
- It is not clear what additional information the REF gives to funders
- The real value of research may take a long time to become clear.

It was the great French physicist and mathematician, Blaise Pascale, who said "I hold it equally impossible to know the parts without knowing the whole and to know the whole without knowing the parts in detail." Never has this been more important than today.

Focussing on the 'R', i.e. research, in UKRI's remit, and taking biomedical sciences as an example, for the past 25 years we have really been in a post-genomic world, exploring how genes encode proteins and affect cells. What is becoming more apparent is that, as well as working in specific domains, we need to work across the whole spatial scale. That is, we need to be able to reassemble complexity from the genetic scale right the way up to us as humans. This has never been more important than today in the middle of a pandemic.

The Government's R&D Roadmap, together with the Industrial Strategy, present clear challenges – healthy aging is one which The Physiological Society is very interested in. There is also a clear commitment by Government to double R&D spend to £22 billion by 2025.

The Knowledge Exchange Framework provides a specific channel for translating research into impact. In the context of today's pandemic, the signs of a mature country include its ability to respond quickly, re-purpose and re-align activity – and the UK is doing pretty well in this regard.

One of the challenges for UKRI is to set up a funding framework which can still focus on the reductive aspects of our science while not losing sight of the whole. Covid-19 is a multi-organ disease and this is classically where three different disciplines meet – physiology, neuroscience and immunology. To be able to set up funding structures in response mode to deal with this kind of challenge is very important.

The Haldane Principle

The Haldane Principle has always underpinned the philosophy behind the British funding of science and again I am pleased to see aspects of the Haldane Principle in the mission of UKRI.

Of course, discovery science and mission science are not mutually exclusive. History is littered with prolific examples of where mission can drive discovery. Look at war efforts where we have made many advances in medicine and surgery. The NASA moon programme really advanced materials science and communication systems.

However, in my view there are two big issues that need addressing in the world of research funding for UK science. First is the pressure on the QR support model. This is the basis for quality research and the reality is that, in research-intensive universities, this model is creating huge deficits, especially for charitable QR streams.

Second is the Research Excellence Framework (REF), which is the framework to help distribution within QR. Having sat on these panels over the last two exercises, I wonder if REF is fit for purpose? It is very costly in terms of both time and money. Hundreds of millions of pounds are spent on running this exercise every six or seven years. Yet, what does it tell us that we do not already know, over and above published metrics?

Universities want to know how academic success is assessed: what is the timeframe over which it is evaluated and what are the appropriate metrics? The answers may be different in mission science and discovery science.

Mission science is more linear, it is easier to put metrics on it because milestones can be set where measurements can be made (e.g. make a vaccine). Discovery science, on the other hand, is much more difficult. It is non-linear and hard to quantify because the timeframes are very long. In fact, history is often the best judge of success in this area and the discovery can often go beyond many parliaments.

Academics are really left with the question: 'If Government is going to put in £22 billion of funding – that is, doubling the funding budget – then what will it be looking for?' What will be the timeframe? What will success look like?

After all, success, in terms of quality, can often take a long time to come through the system. □

Making the most of our innovative start-ups

Priya Guha

SUMMARY

- The UK already has a strong innovation ecosystem
- The Covid-19 pandemic has seen accelerated adoption of new technology
- The record of the industry on equality, diversity and inclusion is poor
- There is an opportunity to address this agenda in building a post-Covid economy
- More must be done to support businesses that are scaling up.

Silicon Valley is often talked about as the centre for innovation and commercialisation. The reality is, Silicon Valley is a very complex beast, made up of lots of different factors. Breaking it down, it incorporates some really fantastic academic institutions, an investor base and a very strong government presence. The Second World War stimulated research on the US West Coast and led to many of the innovations we are familiar with today, including things like the internet. And on top of that there is talent, people constantly up-skilling and reapplying skills to new and innovative ideas and businesses.

So what happens when that model is translated to the UK? This country already has a very strong innovation ecosystem for the commercialisation of companies. Of course, Covid-19 has hit that quite starkly, both in terms of the broader economy but also in terms of the ability of start-ups to retain their talent, to be able to get the investment they need and to be able to retain their customer-facing market activity.

This is why intervention from the Government was crucial, in particular the £1.25 billion package of Covid support for small businesses of all shapes and sizes, but especially for start-ups using technology with plans to scale-up. Innovate UK managed about £750 million of that figure, making it available in different forms from small grants for Covid-related issues to innovation loans in support of the commercialisation of new technologies.

While Covid-19 has been one of the blips the start-up system has had to face, the reality is the crisis has been a catalyst for the adoption of new technology. Pre-pandemic, around 8% of the UK's population were comfortable with an online GP appointment. That has changed completely. Now about 80% of the British population are willing to do so. It has accelerated technological adoption and provided an opportunity, therefore, to rebuild the economy post-pandemic with innovation at its front and centre.

Looking forward to that post-Covid recovery, I want to focus on two areas that are both opportunities and challenges. First is the issue of equality, diversity and inclusion in the economy and particularly in the tech sector.

Figures for equality, diversity and inclusion in tech at the end of 2020 are quite stark. Only 1p in every £1 of UK investment goes to female founders. Further, black founders in the UK have only had access to 0.24% of capital.

Yet we now have an opportunity to build equality, diversity and inclusion into the design of post-Covid systems, making sure algorithms are not biased towards the small sector of the population on which they have been originally tested. The reality is that companies can only achieve full-market opportunity by designing products that appeal to the broad population, including women and minorities. If the innovation economy is to drive future economic growth, then designing in an inclusive way and thinking about a product that serves the whole market are essential considerations.

For me, equality, diversity and inclusion also have to be a really fundamental part of how we think about investment. An important factor to consider is how we track the data relating to investment – whether private sector or indeed Government finance. I strongly believe that Government investment can spur behavioural change in areas where, historically, there has been under-representation of certain groups.

Scale-ups happen at a later stage of the innovation journey, but this is really important economically because at this point the start-up's ideas are commercially viable, with the potential to reach international markets and go global, bringing economic benefit back to the UK.

In the UK, we have historically been very strong

Priya Guha is a Venture Partner at Merian Ventures, investing in women-led innovation. She is a member of the Innovate UK Council, a Non-Executive Director at the Digital Catapult and an Adjunct Faculty member at the Ashridge Hult Business School. She was previously General Manager for RocketSpace, and before that a career diplomat. As well as being on a number of Boards, Priya was named in the 2020 Top 50 Most Influential Women in Technology for the third year running.

Government investment can spur behavioural change in areas where, historically, there has been under-representation of certain groups.

Scale-up is a really important area for UKRI to consider as it looks to provide support to later stage commercialisation.

on scale-ups. We have about 33,000 scale-ups in the UK according to the latest reports, but there are barriers to having more here in the UK. One of the key questions for UKRI and the broader ecosystem is how they can be supported.

In their recent report on the status of funding, British Patient Capital highlighted that B-rounds or rounds later than Series B in the UK are generally about half of the size of other funding rounds. The consequence is that scale-ups in the UK are vulnerable to takeovers from the USA or will find their global market potential limited because they are in a weaker financial position than their competitors.

So scale-up is a really important area for UKRI to consider as it looks to provide support to later stage commercialisation. Such support brings economic value. Those 33,000 businesses are employing about 3.5 million people right here in the UK.

There is now an opportunity to 'build back better' and to have diversity and inclusion at the heart of it. That means building an innovation ecosystem that is producing the economic value our research merits and doing so in a way that involves the whole of the UK economy. The economic and societal value of our innovation economy needs to benefit the whole of the UK for it to be successful, wherever you come from and whoever you are. ❐

The debate

In the panel session that followed the main presentations, questions were raised about: international comparisons; interdisciplinary efforts; inclusivity and diversity; and long-term considerations.

How does the UK system compare to those of other countries? The UK is starting with a very low baseline of investment, and much can be learned from overseas partners. The question of where to prioritise new funding is important and will help in the re-balancing of the system, including the issue of investment in institutions outside the universities. There is a wide diversity in research and innovation landscapes around the globe, though, and some elements of these systems would be harder to adopt than others.

With UKRI, there is a new opportunity for the Research Councils to cooperate more closely on interdisciplinary projects. This brings together parts of the system that otherwise might not have met.

There is also a need to connect bottom-up and top-down approaches in order to capture the extraordinary vibrancy of bottom-up (especially in the innovation context) with a top-down function to enable realisation of new ideas. Bringing Innovate UK under the umbrella of UKRI allows a more structured approach.

Value and difference

The UK must have a system that values a wide range of careers and is inclusive to all. UKRI has to effectively assess research and innovation in a way that captures both value and difference, and supports portfolio careers. It should be quite acceptable for academics to have business interests, and likewise for business people to have academic interests – and make it the norm that these two can work in parallel. In this world, systems engineers are crucial, but systems thinking comes from a wide variety of backgrounds.

A question was posed about the main priorities for UKRI moving forward. In the short term, an initial step would be to ensure joined up thinking on R&D in the Government's Spending Review. This will be crucial in creating an R&D 'build back better' system. In the longer term, there needs to be a shift to a wider and more inclusive view of research and innovation where everyone's contribution is recognised and valued. This is vital in building a much more inclusive picture of a knowledge economy.

We need to share our excitement, enthusiasm and positivity about our ability to solve the problems we are facing. ❐

FURTHER INFORMATION

UKRI
www.ukri.org

UK Research and Development Roadmap
www.gov.uk/government/publications/uk-research-and-development-roadmap

British Patient Capital
www.britishpatientcapital.co.uk

Nesta
www.nesta.org.uk

The Foundation Future Leaders Programme held its first national conference online on 17-19 November 2020. Entitled *Government, Research, Industry – Looking to the Future*, it examined the ways in which these three drivers of the economy might develop. The keynote speaker on the first day was the Government's Chief Scientific Adviser Sir Patrick Vallance, who outlined the role of science advice in Government.

The role of the Government's Chief Scientific Adviser

Patrick Vallance

SUMMARY

- The role of science in advising Government has come to the fore since the Second World War
- There is a Chief Scientific Adviser and team in nearly every Government Department
- There needs to be a clearer understanding about the role of R&D in improving Departmental performance
- During emergencies, the Government naturally turns to science
- Diversity is extremely important in science advice.

At the end of the 19th century, people were already thinking about the role of science in Government. It came to prominence during the Second World War when science was instrumental in the UK's response. After that, people asked themselves, if science had been so important during wartime could it also be important during peacetime? That led to the establishment of the Chief Scientific Adviser and the start of a system for providing science advice in Government. From that moment forward, science has been most prominent during times of emergency and crisis.

Seeking advice

Before agreeing to take this role, I sought advice from various people, including previous cabinet secretaries. One told me: "If I look across my experience, science was good in parts, it was effective sometimes and really important sometimes, yet it wasn't embedded in policy-making and decision-making in the way, for example, that economics was."

His advice to me? "See if you can get science into the same place, where it is as indispensable and integrated a part of policy-thinking as it can be." I took that challenge very seriously: how to get scientists at the table when policy discussions are taking place? The challenge is to move from a Government process that says "This is a scientific problem; I'll ask a scientist", to one that says "This is a policy area; is there an insight that only a scientist or an engineer can bring to it?"

When I joined, I instigated a review of the place of science in Government. The report, *The Science Capability Review*[1], was published in 2019. It outlined how science could be more integrated in the workings of Government.

There is a Chief Scientific Adviser and team in almost every Department. Yet, over the last decade or more, the funding for science and R&D had decreased in many cases. There had been a reduction in budgets, leading to a decrease in capability, which needed to be reversed.

Defining the system

Now, in order for science to be effective in a Department, the system needs definition – what is the process and who will give this science advice? It cannot just be a single Chief Scientific Adviser; it needs to be a team and a group of people who can integrate the policy decisions.

In addition, Departments should define their research interests. This should not be seen as a weakness, but a recognition of areas where more information is needed in order better to formulate policy and determine the future direction. Departments have been asked to publish areas of research interest on an annual basis. The next step will be to identify the common themes that could be important for Government as a whole.

One recommendation of the Review was to protect – and indeed enhance – the proportion of

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See if you can get science into the same place, where it is as indispensable and integrated a part of policy-thinking as it can be.

Any business choosing to invest a small fraction of 1% of its income in R&D effectively defines itself as a low-growth, commodity-based, low-innovation company.

a Department's budget allocated for R&D and science. In some Departments the percentage spend is only a fraction of 1%. Any business choosing to invest a small fraction of 1% of its income in R&D effectively defines itself as a low-growth, commodity-based, low-innovation company. There needs to be a much clearer ambition about the spend on R&D and science in order to improve Departmental performance.

There are a number of Public Sector Research Establishments, such as the Met Office and the National Physical Laboratory. PSREs are important parts of Government science, but not always utilised as effectively as they could be. Some have the potential to be truly national labs, driving areas of applied research forward and providing links locally to businesses and organisations: they can be an important part of a growth agenda.

The Review also looked at skills and technologies. The civil service is not full of scientists and engineers: a couple of years ago only about 10% of the intake had a science or engineering degree. If that continues it will perpetuate a relative dearth of people who can be at the table when science and engineering decisions are being made. These professionals also need tools and techniques such as data visualisation to help in the formulation of policy.

Horizon scanning

One other requirement for Government is good horizon scanning. The Government Office for Science has delivered some Foresight projects which try to understand current trajectories. However, a much better approach to technology-scanning is also needed, to understand how academia and industry can be brought together to plan a strategy for technologies that we know we are going to need. That is critical and UKRI is a critical part of that.

During emergencies, the Government naturally turns to science. The Scientific Advisory Group for Emergencies (SAGE) has been in existence for 12 years: it has created a formal mechanism to pull together experts into a body that can offer integrated science advice.

As Chief Scientific Adviser, I was involved in three episodes of SAGE prior to Covid-19. The first related to the Novichok poisonings in Salisbury, which obviously required integrated science advice. A second was about the Toddbrook Dam where science advice was needed to evaluate the potential consequences of a dam rupture. There was also a precautionary SAGE regarding the outbreaks of Ebola in the Democratic Republic of Congo. Those were normal SAGE procedures with a couple of meetings, where advice was given and the problem was resolved. Clearly, the current pandemic is dramatically different.

In early January 2020, I alerted my team to activate SAGE because of the situation developing in China. We started to assemble experts and on 22 January held our first, precautionary SAGE meeting. By mid-November, we had held 68 meetings! There is no fixed membership of SAGE, people are brought in as needed to give advice. Initially, as is normal, SAGE reported into COBRA, but then COBRA stood down and a Covid Task Force within the Cabinet was formed and we gave our outputs direct to the Cabinet, the Prime Minister and the Covid Task Force.

SAGE has already published several hundred papers (usually, nothing is published until after the emergency is over). The membership has been published which is also unusual. All this work has been carried out in the public gaze which has been difficult.

It is right in a democracy that there should be challenge. Scientists do not have all the answers and no group of scientists can be right all the time. In fact, being absolutely right is impossible in a changing situation, therefore one of the challenges is to give advice that is properly framed in terms of uncertainties and to make sure politicians understand what those uncertainties mean. There is no doubt that this crisis has put science right in the line of sight of politicians!

Politicians do not just rely on the output from SAGE or the input from the Government Chief Scientific Adviser. They get inputs from the Chief Medical Officer, operational advice, economic advice and many other types of advice – all of which must be taken into account when weighing decisions.

The advice from SAGE has been open to scrutiny because the papers have been published. Other advice has not, which has created some asymmetry about the totality of advice that goes into decision making.

My experience

Reflecting on my experience to date as GCSA, there are several thoughts that come to mind. Diversity is incredibly important in science advice: input from people with different backgrounds in academia, industry and other places.

Transparency is important and it is also necessary to recognise that advice from SAGE is not the only input to Government.

Partnership is a vital element. The fact that the Chief Medical Officer and I have worked together as doctors has been incredibly important.

We were hampered early on by poor data from various sources. One big lesson for tackling future emergencies is that we should be looking right now at who owns relevant data, where are these data, how does the data flow into analytics and how does analytics turn into information? That needs to be done in advance for items on the National Risk Register[2].

As a Chief Scientific Adviser, I have found it important to try to drown out the cacophony, the noise, while finding and listening to the voices I need to hear from. There is also a need to find time to reflect on what we are trying to achieve. The day-to-day is very busy but it is essential to find time to think about the big picture.

Partnership is such a vital element. The fact that, in this particular case, the Chief Medical Officer and I go back a long way and have worked together as doctors has been incredibly important. The ability to share the difficulties and the opportunities with someone else has been crucial.

Finally, the only way to make this work is to stay true to the science.

This emergency has been an extraordinary journey. I will end with the observation that all of the CSAs I have worked with, once they step down, continue to hanker for the excitement, the diversity and the interest of what goes on in Government! □

1. www.gov.uk/government/publications/government-science-capability-review
2. www.gov.uk/government/publications/national-risk-register-2020

Bringing together research, industry and policy making

Dr Fay Bound Alberti reviews the Foundation Future Leaders first annual conference.

The first annual Foundation Future Leaders conference brought together over 500 mid-career participants from the civil service, universities, research and industry to explore such questions as:

- How does Government use science?
- How does society encourage innovation in industry?
- What is the place of universities in tomorrow's world?

Science and Government

The first day, which focussed on science and Government, used Covid-19 as a critical case-study. The conference was opened by Lord Willetts, Chair of Foundation for Science and Technology and a former science minister. The keynote speaker was the Government Chief Scientific Adviser Sir Patrick Vallance, who noted that while science is now embedded in Government, it has not until recently had the same importance as, say, economics.

He argued that science policy needs to form part of all branches of Government structure, with R&D budgets increased and protected, and sustained engagement between business, policy and research, in order to ensure UK competitiveness and societal improvement (*Science Capability Review*[1], 2019).

The subsequent panel discussion included Jo Shanmugalingam, Director General, Industrial Strategy, Science and Innovation, Department for Business, Energy & Industrial Strategy (BEIS); Niva Thiruchelvam, Deputy Director of Net Zero in HM Treasury; and two Foundation Future Fellows – Dr Eluned Lewis, Defence Equipment and Support Senior Fellow, Ministry of Defence, and Dr Caroline Pritchard, Impact Manager, National Measurement Laboratory.

Critical take-home messages included the need to incorporate regional perspectives, to ensure science is heard in times of calm as well as crisis, and to engage with Equality and Diversity to meet the challenges and opportunities ahead.

The industrial dimension

Research and innovation in industry was the focus of the second day of the conference which was chaired by Jonathan Neale, Chief Operating Officer of McLaren Group. Keynote addresses were given by Dr Loubna Bouarfa, founder and CEO of Okra Technologies, on her experience in AI and medicine, and also by Steve Rees, Vice-President for Discovery Biology at AstraZeneca.

Both speakers considered the ecosystems around innovation, the importance of leadership and the routes to implementation. Inclusive working environments were stressed, along with the need for collaboration and a willingness to take risks.

The audience asked how the 'freedom to fail' ideal was compatible with the need to succeed,

Keynote addresses covered topics that included the use of AI in medicine.

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especially at vulnerable career stages. Another theme in the questions was how ethics, innovation and commercialism were compatible goals.

These and related questions were addressed by the speakers who were joined by Anusha Shah, Director of Resilient Cities, Arcadis. In particular, he highlighted the need for a systems approach, with investment in societal good by private businesses as well as governments.

The panel was also joined by Foundation Future Leaders Jade Carlotta-Jones, Technology Associate at BP and Dr Karl Surmacz, Principal Data Scientist at McLaren Applied Technologies. Both spoke of the value of the Foundation Future Leaders programme in illuminating links between science, industry and Government.

The place of research

The third day of the conference had as its theme Science, Technology and Research in Universities and was chaired by Dr Rebekah Widdowfield, Chief Executive of the Royal Society of Edinburgh. The keynote speech was given by Professor Dame Nancy Rothwell, President and Vice Chancellor of the University of Manchester, and Chair of the Russell Group of universities.

Dame Nancy highlighted the unique purpose of universities, with academic freedom and freedom of speech as their key characteristics. Yet leaders of universities need the same skills as leaders in science, she stressed. These include credibility, experience, an ability to prioritise, and strategic and effective communication. Cross-disciplinary activities are among the most difficult areas to get right. Indeed, this was a recurring theme throughout the conference. While interdisciplinarity and collaboration are critical for impact, they are hard to achieve without mindful and supportive practices.

Professor David Mba, Pro-Vice Chancellor (Research & Enterprise), De Montfort University, talked about the differences between the post-92 universities to those in the Russell Group, and the need for Diversity and Inclusion to meet the needs of a diverse society. Professor Tim Bedford, Associate Principal at Strathclyde University, highlighted the importance of recognising and rewarding innovation, by tailoring opportunities for those who do not fit into traditional career pathways.

Foundation Future Leaders Dr Helen Dodd, Professor in the School of Psychology and Clinical Language Sciences at the University of Reading, and Dr Benjamin Lichman, Lecturer in Plant Biology at the University of York, stressed the funding challenges arising from the focus on 'impact' as a strategy. They also reflected on the need to balance long-term basic research with that which is impactful and translational. These are challenges for funders, industry and Government as well as researchers. □

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[1] www.gov.uk/government/publications/government-science-capability-review

A recurring theme throughout the conference was how cross-disciplinary activities are among the most difficult areas to get right.

CONTEXT

Online teaching and learning have been available in some subjects in a number of UK universities for several years, but the overwhelming majority of teaching and learning in UK Higher Education has been delivered face-to-face. That all changed with the Covid-19 pandemic, and universities across the country (and indeed the world) have had to introduce primarily online teaching since March 2020.

While most of the focus has been on the immediate issues of delivering education to current students, experts in Higher Education pedagogy have begun to consider the lessons which have been learned over this period, and how this might affect teaching and learning in the future, once the Covid pandemic has passed.

The Foundation wanted to bring this nascent conversation to a wider audience, and explore wider issues of quality, technology and regulation. On 25 November 2020, it brought together the Minister for Higher Education, a Pro Vice Chancellor Education from a leading UK university and the Chief Executive of Jisc, to discuss the issues. All the presentations and audio from the event can be found at: www.foundation.org.uk/Events/2020/Online-teaching-in-higher-education-post-Covid

Making the most of digital technologies to enhance study

Michelle Donelan

SUMMARY

- The availability of digital communications has helped education function through the pandemic
- The Government will not risk a 'lost generation' through disruption of students' education
- Universities are becoming much more adept at blended learning strategies
- Flexibility, accessibility and innovation are core values for tomorrow's universities
- A review of digital technology in education will help identify how to make the most of these tools.

The UK finds itself in the middle of a pandemic at a time when the world has never been so connected. The scientific and research advances that we have seen, together with the leaps in recent decades, have allowed us to communicate far better than we could have otherwise.

Some 30 years ago, Sir Tim Berners Lee set out his plans to create the World Wide Web. He sent his proposals to fellow scientists in CERN, the European Nuclear Research Agency in Switzerland, which would lay the foundations of the web and change the world forever; the way we live, the way we work and the way we connect – as well as the way we learn. The impact on education and the sharing of knowledge has been, quite frankly, staggering.

If the pandemic had occurred just 15 years ago, the response would have been much more difficult. Without smart phones or today's fast internet speeds, there would have been a lack of infrastructure and life would have been even tougher for families, for businesses and for students.

While everyone faces stern national restrictions, the Government is clear that education must be prioritised. The younger generation cannot put their lives – or their academic journeys – on hold.

I was the first in my family to go to university. It helped change the course of my life as it will for so many students studying today. So we cannot and will not risk a 'lost generation'. It is possible to keep Higher Education going through innovations in technology.

Universities can be so much more flexible with blended learning, reducing the number of students on campus at any one time and remaining Covid secure. At a visit to Imperial College London, I saw how their blended offer was delivering postgraduate study. The business class that I attended was catering for students virtually, including students that were self-isolating, as well as students that were overseas. They were all interacting with the lecturers and with one another. This is benefitting students right now and will lead to greater opportunities in the delivery and accessibility of higher education in the future.

Sotheby's School of Art is a magnet for international students in particular. Many current students have not been able to travel as yet, but the

Michelle Donelan MP was appointed Minister of State for Universities at the Department for Education in February 2020. She has been the Conservative MP for Chippenham since 2015. She was a Government Whip from July 2019 to February 2020 and was also an unpaid Parliamentary Under Secretary of State at the Department for Education covering the maternity leave of a fellow MP from September 2019 to February 2020.

The University of Worcestershire has developed an online case study format which aims to give undergraduate paramedics realistic simulated scenarios.


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technology means there has not been a gap in provision at all.

In May 2020, I set up a Higher Education Task Force to bring together the sector, to respond to challenges both during the pandemic and also afterwards. I hope that this will be a long-term venture bringing together the Government and HE institutions in order to work closely and collaboratively.

The Government clearly has a role to play in this area, which is why it announced a stabilisation package for the sector in May, to provide certainty. It also announced a restructure regime. The Department for Business, Energy and Industrial Strategy (BEIS) announced almost £280 million in funding as well.

Flexibility

Universities need to become more flexible and accessible – and more innovative. This is a priority for the Government. The economy is in a process of rapid change. This is driven by the internet and remote communications, but the pandemic is accelerating these changes. More students should be encouraged to take STEM subjects, so that the country can meet current and the future skills gaps that we have.

Recently, the Government announced its commitment to introduce a Lifelong Learning Loan Entitlement as part of a Lifetime Skills Guarantee. This will make HE much more flexible and unlock it as a tool for people at different ages and stages of life: it could be really transformational in terms of mobility.

Universities need to become more flexible and accessible – and more innovative.

This is why the Government is also establishing initiatives such as Institutes of Technology to help meet STEM needs, working with employers and Local Enterprise Partnerships. We have funded the Institute of Coding to help improve digital skills at NVQ Levels 6 and 7.

The University of Worcestershire has developed an online case study format for undergraduate paramedics which provides images and videos of scenes of realistic, simulated patients. It enables students to question the patients through microphones and chat functions, so bringing alive these scenarios.

Employability

It is important to enable students to augment their academic knowledge with employability skills through the use of technology – capabilities such as project management, leadership, presentational and communication skills. De Montfort University, for example, has delivered a Covid-19 volunteer digital support scheme to assist the Leicester SME business community.

We have also commissioned, along with the Chair of the Office for Students, a review of how digital technology has been utilised to deliver remote teaching and learning across the sector since the start of the pandemic. This is looking at the challenges in this area including issues like digital poverty. It will help us make best use of technology and give us ideas on how universities can better maximise opportunities.

The pace of change recently has been phenomenal, but the Higher Education sector has shown itself to be extremely capable. The process of ensuring that students are prioritised and that we can achieve genuine social mobility will remain a priority for the future. ❐

How best to employ developing technologies

Paul Feldman

SUMMARY

- Online teaching will be a permanent feature of tertiary education within a spectrum of mainstream offerings
- There are challenges about how practical subjects and the creative arts make use of online
- The HE sector needs to collaborate much more on the development of materials
- With the world of work changing, education needs to reflect the new needs
- AI will have a profound influence on future teaching and learning environments.

When Covid hit, Jisc carried out several collaborative exercises with the Higher Education sector to look at how we learn lessons from the pandemic[1] and we did a very similar exercise in Further Education as well[2], with the AOC, which came up with very similar responses. However, digital poverty is worse in FE.

In both studies, we looked at how we can help deal with the current year and then to help the sector 'build back better'. It was important to frame this within a strategic context. There was work already going on to develop a vision for 2030, so we included those insights. Under that programme we had set out, a couple of years ago, our vision for the impact of a fourth industrial revolution on the way that we teach. That gives a coherent picture that can set a strategy for our member institutions.

We talked to over a thousand people in the HE sector. The clear messages from lecturers, from students and from senior leaders was 'there is something good in being online that we want to build on'. What is happening in the current academic year is quite different from what was done in an emergency way in March and the summer term of 2020, though.

The value of online

There were key messages on digital poverty, from students, from leaders and from lecturers. But there is a real feeling that online has value and we have to use it.

There are, of course, real challenges about the way practical subjects and the creative arts make use of online in order to enable the transformation seen in teaching other subjects.

Looking at the detail, there was a clear view from lecturers that they can see the value, particularly during the pandemic, but also going forward. Concerns focussed, unsurprisingly, on how disadvantaged students can take part in this mode of learning. Pre-pandemic, 49% of lecturers felt confident in this space. By the start of the current academic year, 75% lecturers felt confident – partly through experience and partly through the work that the sector had done to train them and give them better tools.

While learners may have finally achieved their dream of sitting in bed and getting their teaching, they remain concerned about the lack of interactivity and feel online is not dealing with this. Yet, using technology to create interactivity is a solvable problem. A Woman's Hour programme in early 2020, pre-Covid, featured two young women who would open up Facetime of an evening and keep it open as they went about cooking, studying, very occasionally talking. For them this was meeting and interaction. Ultimately, no-one is suggesting that face-to-face is dead, but the challenge is using technology to enhance the campus experience.

There are a whole set of challenges in preparing for 2021-22. First, the use of online resources has to be planned in a strategic way. Every institution needs to develop a top-down view on how digital is going to change the way it teaches.

Another challenge for the sector is how to collaborate in creating materials. Certainly, a Jisc view is that it would not be helpful to see 150 different ways of explaining the same thing because this is an expensive way to do online teaching – in some sectors online looks to be the cheaper option, in teaching it is not. The metric used in FE is that it takes 10 hours of lecturers' time to create one hour of teaching. As we look to the new technologies the figure will be much higher – virtual reality, for example, is really expensive to start with. So the sector needs to work together on that.

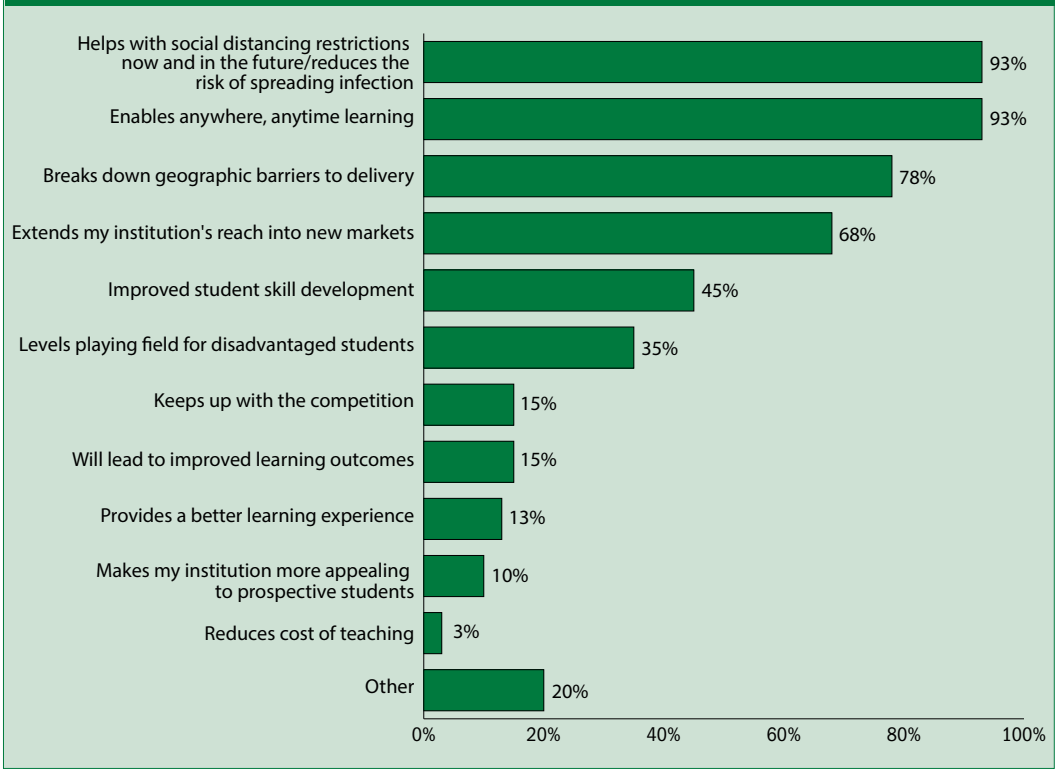
It is not right just to take face-to-face and

Dr Paul Feldman is Chief Executive of Jisc, a position he took up in October 2015. Before that, he was an executive partner at Gartner UK, a technology research and advisory firm. He spent over 20 years in financial services at Nationwide Building Society, Barclays Bank and First Data EMEA, both in IT and business roles. He has also worked in knowledge-based IT companies including Thomson Reuters Legal UK and the Intellectual Property Office. Jisc is a membership organisation and is the UK's digital body for tertiary education and research.

While learners may have finally achieved their dream of sitting in bed and getting their teaching, they remain concerned about the lack of interactivity and feel online is not dealing with this.

Blended learning can offer flexible university teaching – reducing the number of students on campus at any one time and remaining Covid secure.

Figure 1. Lecturer views on advantages of online learning.



automate it. Universities need to look closely at their curriculums and design them for the future: students should be involved in that. Furthermore, everyone needs to get together and look at how to fight digital poverty and data poverty.

A vision for 2030

The vision the HE sector gave Jisc for 2030 was that by then: 'UK Higher Education is regarded as world class because it is attractive to all students, seamlessly spans the physical and virtual worlds and is of the highest academic quality'. Everyone accepts this is necessary in order to remain competitive. The teaching that is going on at the moment is very much lecturer-led, pushed out to students. Over the next 10 years, we expect much more pull from students – students in charge of their own learning, with technology increasingly supporting them.

So by 2030 students would control their own learning with lecturers supporting them and challenging them, in order to ensure they have the right skills. Of course by this stage online is fully embedded. Even the mainstream, campus-based model, will be based on student-led learning.

Technologies can transform the way we teach because they can transform the way students learn. Artificial Intelligence is the key to doing this, along with virtual reality and learning analytics. Over the next 10-15 years, AI can transform the learning experience and the way a student's capabilities are assessed, getting away from high-stakes exams and allowing them to achieve qualifications when they are capable, as opposed to within a particular time-frame. This will, of course, mean a rethink of how we use our campuses.

Skills for the future

When thinking about the future, it is important to remember that the world of work is changing. People's careers will change dramatically over the coming years and universities need to rethink not just the way they teach, but what they teach. Helping a lawyer remember the law, helping an accountant think about how to put accounts together or a doctor to diagnose are all skills for today, not tomorrow. Technology is going to be better at these current skills than people, so students need to understand how to reinvent themselves, how to take part in lifelong learning, but most importantly, how to access those critical skills and especially human-to-human skills which are our future.

The key need for the UK is to get to grips with AI in teaching and to be a leader in this. Today, China is the leader in this area. If the UK wants to be the leader and wants to be in charge of our own way of teaching, the UK must invest in the use of AI, certainly in tertiary education. □

It is important to remember that the world of work is changing. People's careers will change dramatically over the coming years and universities need to rethink not just the way they teach, but what they teach.

[1] www.jisc.ac.uk/learning-and-teaching-reimagined
[2] www.jisc.ac.uk/shaping-the-digital-future-of-fe-and-skills

Change is part of the DNA of Higher Education

Sarah Speight

SUMMARY

- Learning and change are part of the DNA of universities
- In 2020, the biggest challenge has been 'pace', both for staff and students
- The loss of the social aspects of learning have been felt by students and staff
- The students of 2020 are not a 'lost generation'; they have proved remarkably resilient
- Digital poverty is a challenge to be tackled and overcome – and it affects staff as well as students.

There is still some confusion in the HE sector about exactly what we are trying to achieve with digital technologies. Terms like 'online teaching', 'blended learning' and 'remote learning' (the last with slightly unfriendly undertones!) are all in use. So we need to be absolutely clear what we are talking about and make sure that our debate and our discussion are in the right space, as well as in the right place.

Blended learning

My focus is on 'blended learning' which is a pedagogy that is fit for purpose – a pedagogy that makes choices and is designed to support student learning. That means designing in wellbeing, mental health and motivation, all of which are essential ingredients for learning as well as for life.

Blended learning has a strong focus on design, task-differentiated practice, personalisation, engagement and complementarity. Most importantly, it is not hierarchical: it does not judge one practice, technology or tool to be better than another; it is concerned with defining the right tools for the task. The tasks include: knowledge acquisition, enquiry and research, discussion, collaboration, and practice. All must be adapted for each phase of the student journey – first year, second year, third year, postgraduate – and of course for the discipline.

Learning and change are, of course, in the DNA of universities. We are not dinosaurs clinging to the 'sage on the stage' model of transmission. Virtual learning environments have been in use since the 1990s, principally for the management of teaching but increasingly to support its delivery. It was in the 1990s that the concept of blended learning actually emerged.

Some of my earlier work involved Massive Open Online Courses (MOOCs) and the development of the UK-based FutureLearn. MOOCs began in 2008 in North America. They were heralded as a great disrupter, 'the potential end of the university as we know it'. Instead, they caused a ripple in our pedagogies.

We took our MOOC learning into our mainstream to flip, to scaffold, and to develop our skills as facilitators of learning. They taught us the power of video, but especially of audio, the importance of online socialisation and the difference between comment and discussion in a virtual forum.

Setting the pace

In 2020, the biggest challenge has been pace and it continues to be difficult to find time to reflect on our learning. Pace has been really challenging for students and, indeed, some feel they have more work to do than pre-Covid. Among the reasons for this is that there is no excuse for missing a lecture if these are online. If they have been pre-recorded, there is indeed every temptation to rewind the videos constantly and extract every ounce of goodness from them!

Students need more help with 'learning how to learn' in a blended environment. They need help with time management – pacing again – and adapting to a revised diet of coursework and exams. There can also be a cognitive overload, switching from face-to-face in-person teaching to synchronous online and then to asynchronous online.

This is challenging for them and it is not easily captured in their timetable or their schedule. What most universities are doing is building systems to track engagement as opposed to attendance. Until these systems are functioning, there will be a continuing concern about the students

Professor Sarah Speight is Pro Vice Chancellor, Education and Student Experience, University of Nottingham. Her disciplinary background is in European medieval history and archaeology. Prior to Covid-19, Sarah was already involved in online teaching and learning as the academic lead for Nottingham's work with FutureLearn, and for the University's online skills courses for its students in the UK, China and Malaysia.

Students need more help 'learning how to learn' in a blended environment; with time management, and adapting to a revised diet of coursework.

First year students in particular need a digital equivalent of the university coffee shop at the end of the lecture.

VCHAPMAN (CC BY-SA 4.0)

who may fall down the cracks and lose the ability to keep up with their peers.

It is quite clear, though, that the students of 2020 are no 'lost generation'; they are a remarkable generation which has experienced rapid personal and professional growth. I hope employers will recognise that!

In 2020, university staff demonstrated their ability to work together across disciplines in the interest of their students. Our focus has been on collaboration, partnership, support, empathy, engagement, and evaluation.

Social learners

From a student perspective, it is clear where the glue is missing. They need space and time to become social learners again. They need to engage with their content, with their tutors but also with their peers – that is what is most lacking in the current situation.

First year students in particular are struggling to find study buddies and their learning sets. They need a digital equivalent of going for a coffee at the end of the lecture. As staff, we have to help them build academic and social relationships so that they feel they can ask questions in their online sessions.

One of my engineering colleagues made a very relevant observation when he noted that pre-Covid, he would have known the names and the faces of about 75% of the first years in his cohort by the middle of November. This year, at the same stage, he only knows the names and faces of about 10%. So social learning is being compromised for everyone at the moment and it is quite a challenge to demonstrate passion for a subject to a screen of avatars or to your own slides!

Digital poverty is affecting not only a large number of our students, but also staff.

Purposeful pedagogy

We have to build capability, capacity and confidence so that our community can benefit from our purposeful pedagogies, delivered through our blended learning, in a supportive environment that is focussed upon wellbeing, engagement, inclusivity, empathy, passion, and connection.

As we move beyond the pandemic, we need a partnership approach so that UK HE can remain world-leading and student-centric. Our approach to evaluation, to regulation, to monitoring – all need to be fit for purpose in these changed contexts.

A time of crisis is always a time of accelerated learning. We see this in the role that UK HE is playing in the development of tests, treatments, and vaccines for Covid 19. We see it also in the accelerated uptake of blended learning in 2020.

Universities are not seeking to head back to a mis-remembered pre-Covid age of teaching: they will stick to a journey of continuous enhancement. As John Dewey, the American philosopher and educationalist, said: "If we teach our children today as we taught them yesterday, we rob our children of tomorrow." □

Universities are not seeking to head back to a mis-remembered pre-Covid age of teaching: they will stick to a journey of continuous enhancement.

The debate

After the formal presentations, the speakers joined a panel to answer questions from the audience, including: study poverty and digital poverty; expectations; the role of the campus; and data ethics.

A strong baseline of technology-supported learning will develop over time, but the campus experience will remain, not just for social interaction but also for learning. The lack of study space and a conducive environment for learning for some students ('study poverty') sits alongside lack of access to digital tools and networks ('digital poverty') and both need addressing – space in campus can help with this even if teaching is online.

The quality of education is determined primarily by the quality of the lecturers, supplemented by the quality of the technology used to support their teaching. From the Government's perspective, what is important is the quality, quantity and accessibility of teaching, not whether it is online or not. Universities have to give students as much information as possible about what they can expect, while recognising the exceptional circumstances of 2020, including Government decisions on lockdowns.

The panel discussed where we might be in five to 10 years' time and whether technology could lead to the campus becoming less important. Technology will help deliver learning that is better done at a student's own pace, allowing better use of contact time, where lecturers can build and challenge the critical thinking of students. High quality recorded teaching can be used multiple times for different purposes (e.g. for undergraduate courses, lifelong learning opportunities and CPD).

While not replacing the campus, opportunities can arise for other means of interaction, for example, for some international students to take some of their courses in their home countries, or for students who have been ill or unable to travel to benefit from educational opportunities they might otherwise miss.

The ethics of data handling was raised, with universities potentially having extensive information about the online learning patterns of students. It was noted that Jisc and the National Union of Students have jointly developed a code of practice for learning analytics. The key is for students to know how such data may be used.

The UK HE sector had risen to the challenges of 2020. Utilising these new technologies, and with more time to reflect and build once out of the immediate crisis, the UK can become a world leader in blended learning and deliver great outcomes for students. □

FURTHER INFORMATION

BONARD

Advance HE www.advance-he.ac.uk

Association of Colleges www.aoc.co.uk

Jisc www.jisc.ac.uk

Jisc Digital Experience Insights www.jisc.ac.uk/digital-experience-insights

Jisc (2020) *Learning and teaching reimagined: a new dawn for higher education?* www.jisc.ac.uk/learning-and-teaching-reimagined

Jisc (2020) *Shaping the digital future of FE and skills* www.jisc.ac.uk/shaping-the-digital-future-of-fe-and-skills

Jisc (2020) *Code of practice for learning analytics* www.jisc.ac.uk/guides/code-of-practice-for-learning-analytics

Montacute R (2020) *Social Mobility and Covid-19*, Sutton Trust. www.suttontrust.com/wp-content/uploads/2020/04/COVID-19-and-Social-Mobility-1.pdf

QAA (June 2020) *Preserving Quality and Standards Through a Time of Rapid Change: UK Higher Education in 2020-21.* www.qaa.ac.uk/docs/qaa/guidance/preserving-quality-and-standards-through-a-time-of-rapid-change.pdf

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CONTEXT

The Government has committed to reaching net zero emissions by 2050. Even with increasing use of renewable energy, there may be an ongoing need for nuclear power. Since the current fleet of nuclear power stations is coming towards the end of its operational life, decisions will be needed on investments in new nuclear. The Government published its Energy White Paper on 14 December 2020.

To maximise the value of new-build nuclear, options are available for cogeneration – where the heat from nuclear power is used not only to produce power, but also to address some of the 'difficult to decarbonise' energy demands such as domestic heating and hydrogen production. Cogeneration also enables a nuclear plant to be used more flexibly, by switching between electricity generation and cogeneration applications – providing more power when less is available from renewable energy sources. A major policy paper on nuclear cogeneration was published by the Royal Society on 7 October 2020.

Cogeneration should be built into decisions on new nuclear from the start, as they affect decisions on both design and location. A Foundation discussion on 9 December 2020 was therefore timely and brought together the Chair of the Royal Society paper, the Chief Executive of a nuclear energy company and a regulator from the Environment Agency. All the presentations and the audio from the event is available on the Foundation website at: www.foundation.org.uk/Events/2020/Nuclear-Cogeneration-and-Net-Zero

A roadmap for a nuclear future

Robin Grimes

Professor Robin Grimes FRS FREng is the Steele Chair of Energy Materials at Imperial College. In his research, he uses computer simulation techniques to predict the behaviour of materials for energy applications including nuclear fission and fusion, fuel cells and batteries. He is a Fellow of the Royal Society and of the Royal Academy of Engineering. In April 2017 he became Chief Scientific Adviser (Nuclear) to the Ministry of Defence. Between 2013 and 2018 he was Chief Scientific Adviser to the Foreign & Commonwealth Office. He chaired the steering group responsible for the Royal Society Policy Briefing.

SUMMARY

- The UK will need a large increase in electricity supply if it is to reach its 2050 net zero target
- Electricity currently provides less than 20% of total UK energy needs
- Nuclear power can address the intermittency issues associated with renewables
- Small modular reactors and advanced modular reactors can be designed to provide direct heat supply
- There is a real possibility to create a UK supply chain for these new nuclear technologies.

The Royal Society's Policy Briefing on nuclear cogeneration[1] examines how the use of nuclear power could be expanded to improve the overall efficiency and resilience of the UK energy system and so help meet the net zero 2050 goal.

The first consideration is the colossal amount of electricity required to meet the 2050 target. Looking at current UK energy demand, though, electricity is not the largest part of it (17%): heating is considerably bigger (43%), closely followed by transport (40%). To truly decarbonise, the challenge is not just to produce low-carbon electricity, but also to provide more of the heating load via electricity and later to provide decarbonised heat directly.

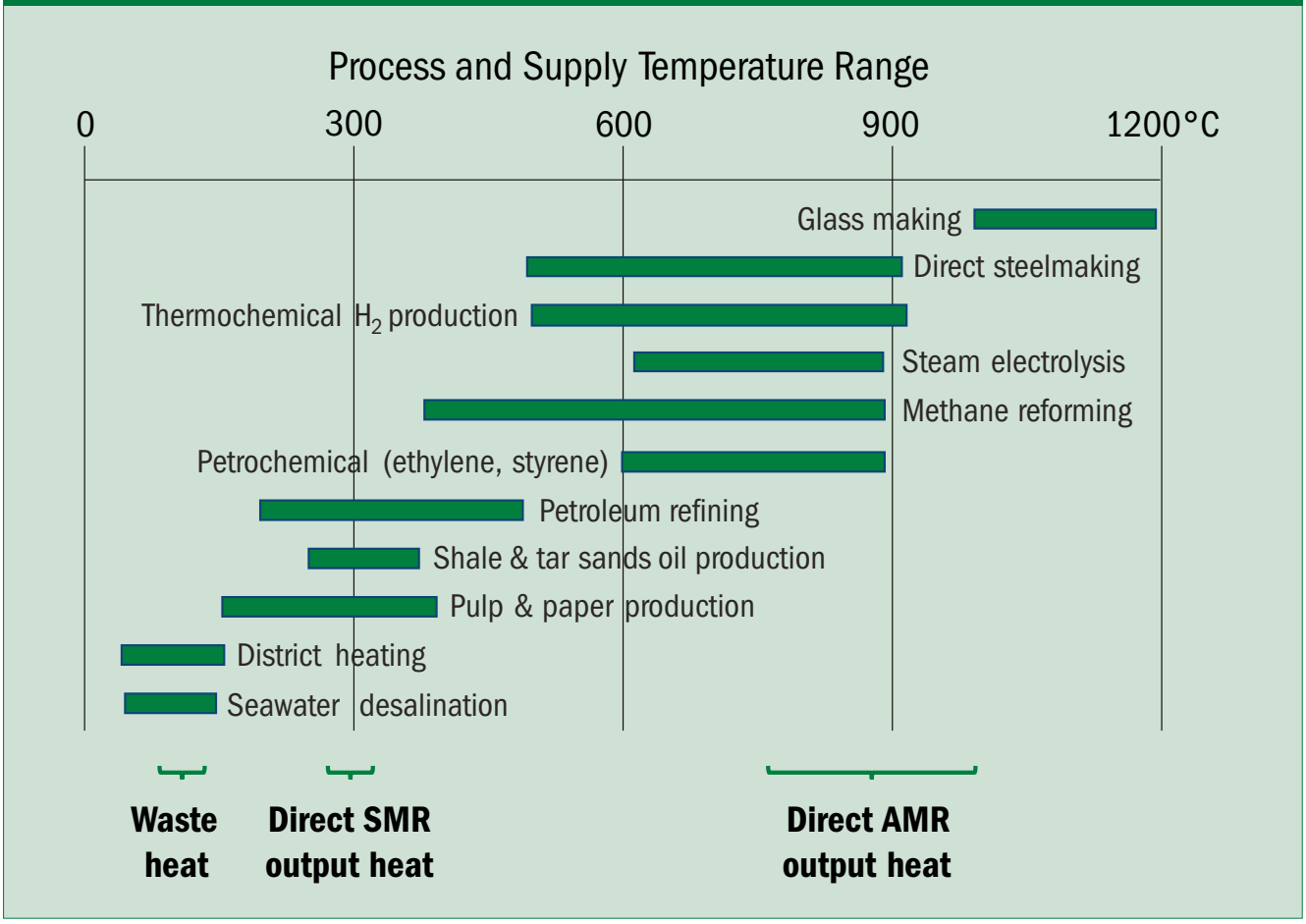
The UK is heading towards a supply grid dominated by renewables. However, at the moment gas is used to make up for intermittency of renewable supply (e.g. for wind-generated electricity when it is not windy, or for solar at night). As fossil fuel is phased out, the intermittency problem is going to grow. The gigawatt nuclear plants of the past 60 years provided low-carbon electricity to meet baseload but many of the existing fleet of reactors are due to be retired in the coming years. Current plans are to replace them with more baseload supply – but that does not tackle the intermittency problem for the grid. How can nuclear contribute?

In conventional nuclear power, much of the energy that is generated is lost as waste heat after the turbines have been driven round. Some of that waste heat can be used to do useful things, such as district heating or the production of hydrogen via electrolysis (which is more efficient if the material being electrolysed – water – is hotter). However, as current plants are not designed to have that heat utilised, any such applications based on modifications would be inefficient and expensive. The new types of reactors – both small modular reactors (SMRs) and advanced modular reactors (AMRs) – are, though, being designed with cogeneration in mind.

It is not all about finding a use for waste heat: the heat from new reactors can be used directly. While waste heat has relatively low temperatures, SMRs (which are based on light water reactor designs) can reach intermediate temperatures, and the high temperatures delivered from AMRs will allow more interesting chemistry at much higher temperatures (see Figure 1).

In this way, not only do new reactors address

Figure 1. Temperature ranges of potential cogeneration applications



the intermittency issue, but they can be used to deliver products which are difficult to decarbonise in other ways: such as ammonia and synthetic fuels, as well as direct hydrogen for the hydrogen economy.

The supply chain

Small modular reactors are based around existing light water reactor technology and there is an opportunity here for the UK, through the Rolls Royce PWR design.

In the UK we are currently doing much of the civil engineering associated with the EDF gigawatt build at Hinkley Point which, for a nuclear plant, is complicated. This is an important first step in developing a supply chain.

Adopting UK SMRs, we could use the UK supply chain for fuel from Springfields and there is the opportunity to use Sheffield Forge Masters for many of the heavy components including the reactor pressure vessel. The majority of other components could also come through a UK supply chain that would include Rolls Royce using the same factory approach employed in aeroengine manufacturing.

The development of a UK nuclear manufacturing supply chain for SMRs would naturally lead to the creation of an AMR reactor supply chain. It would also encourage UK development of new processes that use the AMR high temperature heat output (e.g. to generate H_2, synthetic fuels, etc).

A roadmap

This gives a roadmap for nuclear, starting with current technologies for gigawatt baseload production. SMRs can be used to manage some of the intermittency that renewables create in the grid supply, as well as providing some cogeneration. Looking to AMRs, high temperature applications create the demand for high temperature output – which are, indeed, the same sorts of high temperatures that are provided by fusion. In many ways, then, AMR also allows us to get ready for fusion. ❑

New reactors can be used to deliver products which are difficult to decarbonise in other ways.

[1] https://royalsociety.org/topics-policy/projects/low-carbon-energy-programme/nuclear-cogeneration

The UK is heading towards a supply grid dominated by renewables. However, as fossil fuel is phased out, the intermittency problem is going to grow.

Sustainable energy production

Jo Nettleton

Dr Jo Nettleton is Deputy Director and Head of Radioactive Substances and Installations Regulation at the Environment Agency. Following a career in medical physics and radiation research, Jo joined HSE as a radiation specialist inspector. She moved to join the Nuclear Installations Inspectorate, leading teams to regulate nuclear decommissioning, conventional health & safety and nuclear safeguards, before joining HSE's Hazardous Installations Inspectorate, leading regulation of biological agents, explosives and chemical industries. She joined the Environment Agency in 2015.

SUMMARY

- Using the heat generated in nuclear power plants would make a substantial contribution to sustainable energy production
- New advanced nuclear technologies can build in the ability to capture and deploy this heat energy
- The Environment Agency is working with other regulators to create a framework that ensures safety and protects the environment
- To employ waste heat effectively, new reactors need to be close to communities and industry
- That will require effective engagement with local people and businesses.

The Environment Agency's remit is massive. Among its many roles, it regulates radioactive waste and emissions to air, land and water from MoD sites, civil energy production plants, nuclear legacy and waste facilities. It also regulates non-nuclear uses of radioactive substances, again across a whole range of industries.

Most nuclear plants do not recover waste heat, so about 70% of the energy produced serves no useful purpose. Capturing it and applying it through heating or direct use would make a substantial contribution to sustainable energy production.

While that may not be possible for most existing nuclear plants, it is possible for new designs, both large scale (there are discussions about domestic community heating around Sizewell C) but more particularly for smaller reactors, whether small modular reactors using existing technology with the potential for domestic district heating, or higher-temperature, advanced modular reactors which can be used to provide heat to industrial processes, including hydrogen production. As the reactors are smaller, they can be located much closer to communities or industrial sites – with appropriate safety and environmental protections in place, of course.

The climate is changing, and the world has, in large part, woken up to the challenge. The UN Sustainable Development Goals, for example, are important in directing action and the UK Government is playing its part. The Prime Minister has published his 10 Point Plan which includes hydrogen, advanced nuclear technology and protection of the environment. Innovation is going to be absolutely crucial in meeting those challenges.

The EA works very closely with its partner regulators – mainly the Office for Nuclear Regulation – and our work in this regard aims to develop a framework to protect the environment and ensure safety, while allowing and enabling innovation to happen in the nuclear space.

The Agency is reviewing its processes and guidance to ensure they are appropriate for small reactors and for advanced nuclear technologies. It is working with a wide range of people, including industry, so that everyone knows what to expect in terms of regulation. We need to know what technology we will have to scrutinise and regulate, and we are learning lessons from international experience. We have a wide range of skilled and experienced people working on this, but they need to be upskilled to assess these new technologies and we are currently addressing that.

There are challenges, of course. To employ waste heat effectively, small reactors need to be close to the communities and the industries that are going to use them. That raises questions about safety and environmental protection. We need robust, transparent and open regulation as well as good engagement with local communities in order to work through those challenges.

There will be all sorts of questions about the risk from radioactive processes. What will the implications be for my house price? Will there be more jobs associated with the reactor? What will it do to traffic? There are all sorts of questions but we have experience across a whole range of industries of the types of engagement that we need with communities. While the nuclear sector itself has a great deal of experience in engagement, there are lessons that can be adopted from others.

The option of taking lower-temperature steam for heating, or high-temperature steam for industrial processes, is possible with a reactor as a future power source. There is the potential to develop clusters that use future nuclear power generation, but which at the same time enable hydrogen production, that enable chemical plants which incorporate carbon capture and storage, that drive innovation and economic growth while also contributing to decarbonisation. That really is the prize that everyone would wish to see if cogeneration moves forward in a safe and environmentally secure way. □

Capturing waste heat and applying it through heating or direct use would make a substantial contribution to sustainable energy production.

Delivering an integrated plan for the future

Duncan Hawthorne

SUMMARY

- Many of the ideas for new nuclear have already been proven in the past
- To deliver our energy and climate targets, there needs to be an integrated plan
- To 'build back better', the UK has to build a new generation of nuclear plants with the required flexibility
- It is possible to deliver a UK-sourced solution
- There is only a short timeframe within which to deliver on our net zero ambitions.

When I took up a post in Canada's largest nuclear facility in the late 1990s, the government of Ontario decided to close all of their coal plants. In the UK, flexible gas plants were used to deal with peak load demand. Well, in Canada that role was taken by coal. However, the government decided to remove coal from the equation and create an emissions-free energy production environment.

Now, in the nuclear sector we provided baseload energy, but people did not consume it in that way. Energy was required in a peaky manner, morning and evening – and that peak was met by coal. So the challenge was to remove coal and put an emissions-free source in its place. One strategy was to introduce renewables – wind and solar. The Green Energy Act was brought in to facilitate that. In reality, though, the main component of generating capacity came from nuclear plants. This was achieved through a combination of bringing back into service plants that had been dormant, extending the life of existing units and finding ways to flex their additional capacity.

A good case study is the Bruce Nuclear Facility, which was built as the world's largest in the 1970s, and in fact it had cogeneration capability. This was built into the design because the boilers and reactors were over-sized, producing an excess of steam which the turbines could not accept. Much of that steam was therefore diverted to an 'energy park' which sat right next to the generating station. Any industry that had a demand for high temperature steam – chemical installations, hydroponics, etc – could be supplied with steam from the nuclear station. These industrial units were in fact built adjacent to the main site. The station also produced hydrogen off-peak. Furthermore, we made use of pumped storage: overnight, when demand was low, we could use excess power to pump water uphill and then, in the morning when there was peak demand, the hydro facility would let the water flow down through turbines to produce electricity.

So, the ideas being discussed now to making use of the full energy output from nuclear facilities are not all untried innovations. This time, though, the aim is to design these applications in from the start.

Taking the characteristics of baseload nuclear and comparing this with our consumption habits, it is clear we do not consume power in the way nuclear makes it. So to understand the most efficient strategy for these clean technologies, we need a system-wide approach.

The elephant and the butterfly

We have intermittent wind. I sometimes use the analogy of the elephant and the butterfly: the elephant of nuclear is not agile enough to dance and vary its performance while the butterfly of wind is unpredictable. Without some storage capability and some way to harvest excess energy, it is inevitable that we will create waste.

If we are seriously looking to 'build back better', then the aim must be to build a new generation of nuclear plants that have the necessary flexibility. There are several options that can create UK-centric, flexible, large and small nuclear facilities.

I think of this as our 'going to the moon' challenge. Achieving net zero will require all the imagination, innovation and commitment that we can muster. It will involve a complete transformation of our energy sector and it has to be viewed from that vantage point. It cannot be done with incremental decision-making, there must be a grand plan.

While the Prime Minister's 10 Point Plan is to

Duncan Hawthorne was appointed Chief Executive of Horizon Nuclear Power in May 2016, having been a non-executive Director of Horizon since 2013 and CEO of Bruce Power in Canada, one of the world's largest nuclear power plants, since it was formed in 2001. He is the Former Chairman of the World Association of Nuclear Operators (WANO) and has worked in the power generation business for 40 years, holding senior positions in power companies in the UK, USA and Canada. He is a Fellow of the Institution of Electrical Engineers and of the Institution of Mechanical Engineers.

Achieving net zero will require all the imagination, innovation and commitment that we can muster. There must be a grand plan.

The UK has been stumbling around for at least 20 years and has been very fortunate in being able to extend the life of the existing fleet.

be applauded, it is not enough and there is not enough funding behind it to deliver its goals. There is imagination and vision, but not a cohesive plan to get there. The industry needs that, the supply chain needs that, the young people beginning their careers need that: if we are going to attract the brightest and the best to this industry, they will need a sense of a career that looks like mine – long-term, challenging, exciting, in the same way that the 'going to the moon' speech by J F Kennedy sent recruitment in NASA through the roof.

One saying I often come back to is: 'If you don't know where you are going, any road will take you there.' The UK has been stumbling around for at least 20 years and has been very fortunate in being able to extend the life of the existing fleet. I left Britain in 1997, believing that by 2010 most of the AGRs would be gone. While it is a credit to the operators to have been able to extend the lifetimes till now, these Generation 2 plants should have been replaced more than a decade ago. There is now a very short period in which to create an integrated plan, replace existing capacity and also introduce these new technologies.

There is a vision, but a vision without action is a dream. Let us hope that as a country we are up to the challenge that we have set ourselves. ❐

The debate

After the main presentations, the speakers answered questions posed by the audience, including: timescales, urgency, engagement with local communities and robust planning.

The speakers set out a vision for a nuclear future, but will it translate into a compelling economic and political case – and how soon do we need to get it underway? The extended lifespans of the existing fleet have meant that decisions have been put off for years. However, unless these are taken now, the programme will not play a full part in the decarbonisation of the UK energy system. The country has prevaricated too long. If the investment is not put in now, the programme will not happen.

System-wide analysis

There needs to be a system-wide analysis of the needs and opportunities. How many of these units and where? Designs for SMRs should be simple, straightforward, proven and deliverable. There are currently more than 20 SMR designs being talked about. The UK should narrow down those that are most viable and put support there.

In terms of the economics, it is likely that SMRs and AMRs will be clustered. It may be that in a cluster of, say, eight some will be dedicated to electricity production while others may provide direct heat for industrial applications. This will depend on what is needed in a particular location.

Because these units will be sited much closer to communities and industrial location, a great deal of effort will need to be made to engage with local people in order to convince them that these technologies are safe. There will be robust regulation – and not just of the generating units as chemical plants have their own regulatory requirements – building on the many years of experience the regulators already have. Confidence building will be a joint responsibility for Government, regulator and developer.

There is a clear vision for the future, but this needs to be turned into a detailed plan with timings and figures because without that investors will not be prepared to provide the sums required. Delivering on this vision requires ambition, resolve and commitment. ❐

There is a clear vision for the future, but this needs to be turned into a detailed plan with timings and figures.

FURTHER INFORMATION

10 Point Plan
www.gov.uk/government/publications/the-ten-point-plan-for-a-green-industrial-revolution

Energy White Paper: Powering our Net Zero Future
www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future

Royal Society. Nuclear Cogeneration: civil nuclear in a low-carbon future
https://royalsociety.org/topics-policy/projects/low-carbon-energy-programme/nuclear-cogeneration

Trust, notoriously, is hard to gain and easy to lose. Nevertheless, mistrust of science can have disastrous effects and must be tackled.

Mistrust and risk in a pandemic

Glynis M Breakwell

New ideas, discoveries and technologies are often mistrusted. Science is familiar with mistrust, but it entails doubt, suspicion and uncertainty. It is different from *distrust*, which implies being sure that something or someone should not be trusted.

In mistrust, there is an ongoing process of negotiating the allocation of trust. It is often associated with indecision, vacillation, confusion and ambivalence. It can also trigger emotional responses, particularly fear and anger. Mistrust frequently also involves tentative or anticipatory attempts to attribute blame.

Sir Paul Nurse, in *FST Journal*[1] in 2016, argued eloquently in defence of doubt as a basis for science because it motivates inquiry and the search for empirical proofs. He noted doubt promotes the diversity of ideas and healthy scepticism. He also suggested that the public and policy makers tend to prefer certainties rather than the tentative assertions of science at the edge of discovery. They like the idea that science offers very reliable explanations of complex phenomena.

Public mistrust

When scientists acknowledge that the process is not so simple, and especially when they disagree with each other, public mistrust can occur. The uncertainties that are the lifeblood of scientific development can thus engender unhelpful public doubt and provide scope for the misrepresentation or even rejection of science.

The science community has gone to great lengths over a long time to develop public understanding of, and engagement with, science. These efforts have met with some success. Surveys in the UK indicate that 'scientist' is one of the most trusted professions. Around 55% of those sampled say they trust scientists to tell the truth. However, that still leaves a high level of mistrust. Notably, less affluent and non-graduate members of the public are less likely to consider scientists trustworthy (Ipsos MORI, 2020).

By the end of January 2021, worldwide over 100 million cases of COVID-19 and 2.16 million associated deaths had been reported. Populations have been asked to trust the decisions taken – and the subsequent measures instituted by – their governments in the effort to bring the pandemic under control. People have been asked to accept curtailment of their freedoms and to comply with behavioural restrictions never seen on such a scale.

In the main, governments have justified their actions by saying that they are 'following the science'. This message has been reinforced by establishing additional scientific advisory structures and by supporting major new research programmes.

This level of government reliance on the scientific community to influence and justify its actions is probably unparalleled. As such, it involves risk both for governments and for science: an error by one may undermine both. Of course, it is a risk neither can avoid; getting the response to the pandemic right is too important.

The main risk to the credibility of science has been the range of uncertainties linked to the SARS-CoV-2 virus (including its origin, rate and types of mutation, transmissibility, physical and psychological immediate and long- term effects, responsiveness to prophylactics, vaccination or medical treatments, and the viability of containment via behaviour change). Explaining the complex interactions of these uncertainties and their implications for everyday life would have been difficult enough. The task is made harder because it is not clear when these uncertainties can be resolved. A public thirst for certainty, instead, is paradoxically offered something akin to indefinite uncertainty.

Except, that is, for the one absolute certainty that COVID-19 is a dire threat to everyone. In fact, this was largely the risk message that the scientific community broadcast, calling for everyone to join together in the effort to stem the spread of the virus. The uncertainties were presented but in a way that emphasised the main message of threat.

Research on the social psychological factors influencing people's reactions to the threat of COVID-19 has shown that greater trust of science and scientists is related to feeling personally more at risk of COVID-19 (Breakwell & Jaspal, 2020) leading to a greater likelihood of engaging in COVID-19 preventive behaviour. Feeling at personal risk is strongly positively related to being fearful of COVID-19 and fear, in turn, is also pre-

Professor Emeritus Dame Glynis Breakwell DBE FAcSS is a social psychologist. She is Professor Emeritus at the University of Bath and Visiting Professor at Imperial College London, the University of Surrey and Nottingham Trent University. She led the first research on young people's risk-taking in relation to AIDS/HIV and was part of the first Public Understanding of Science research programme. Her book *Mistrust* will be published in autumn 2021.

The main risk to the credibility of science has been the range of uncertainties linked to the SARS-CoV-2 virus. Explaining these is made harder because it is not clear when these uncertainties can be resolved.

The complexities underlying vaccine development and the nature of clinical trials are difficult to explain in a non-technical yet persuasive way. The counter-rhetoric of the conspiracy theorists is simple and direct.

dictive of a higher likelihood of COVID-19 preventive behaviour (Breakwell, Fino & Jaspal, 2021).

Mistrust of science in the context of the pandemic clearly does matter because it is associated with feeling less at risk and less fearful, and thus being less likely to self-protect. It is worth remembering that mistrust is not simply a product of individuals in isolation coming to an evaluation. Mistrust is elaborated and shared between people. Social representation processes help people to make sense of what is happening, making it possible for abstractions and uncertainties to be simplified and objectified through example and illustration. These processes rely on social interactions (often now virtually through social media). They are the cornerstone of shared uncertainty and shared mistrust (Breakwell, 2020).

Conspiracy theories are a specific form of social representation. Conspiracy theorising is a particular source of mistrust in science because it grabs hold of the doubts and uncertainties that drive development in science and subverts their meaning. Typically, the conspiracy theory gives an alternative account of what is happening that undermines the narrative that is emerging from the scientific research. Conspiracy theories are rarely purely accidental, can serve a wide range of motives (for instance, profit, retaliation, self-aggrandisement, anarchism, or hatred) and can be products of opportunism or misunderstanding.

Conspiracy theories have become a serious problem in the pandemic. They offer the public a spurious certainty about some things and incite fear and mistrust of others. For instance, one early conspiracy theory claimed categorically that 5G caused COVID-19. A later theory claimed COVID-19 was an excuse to mount an orchestrated attack on civil liberties. Both were linked to protests and disorder.

With the development of vaccines against the virus, the focus of conspiracy theories has shifted to vaccination. Their common object is to discredit the efficacy or safety of the vaccine and to encourage people to refuse vaccination. They are also designed to attack the moral standing and motives of those who develop or support vaccination.

These types of conspiracy theory foster mistrust of science. The anti-vaccination conspiracy theories are particularly concerning, given their potential impact upon behaviour. People seeing the vaccine as the hazard, rather than the disease, is truly problematic.

The complexities underlying vaccine development and the nature of clinical trials are difficult to explain in a non-scientific, non-technical yet persuasive way. The counter-rhetoric of the conspiracy theorists is simple and direct – these things are not safe, you can rely on us, why would we mislead you?

Dealing with this sort of appeal is hard unless the public has reason to trust those who reject it. Acceptance of vaccination for COVID-19 is strongly associated with perceived personal risk and generic trust in science and scientists. Where trust is already weak, these conspiracy theories can flourish. These theories are attractive because they claim to explain the inexplicable, they evict uncertainty and they offer people justifications for what they would like to do anyway. They promise a route out of doubt about one thing, by creating doubt elsewhere.

It is imperative that the science community continues to intensify its effort to dispel public mistrust of its motives and outputs. Failure to do so would mean mistrust grows and people will misunderstand or discount the risks they face. Moreover, they will reject or ignore advice about how they can protect themselves and, consequently, further enhance the risk they will encounter.

Promoting resilient, stable trust in science will probably need to be based on finding ways of reassuring the public that science will remain autonomous, not just of Government but also of commercial interests. It will also depend on the scientific community continuing its journey towards greater inclusivity and public accountability. Hopefully, the burden of dealing with mistrust in relation to the pandemic will not fall solely on the shoulders of scientists. Enhanced self-regulation by media channels that currently provide platforms for the dissemination of disinformation would help. □

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[1] *FST Journal* Vol 21 No 8, pp4-5. www.foundation.org.uk/Journal/2016/Volume-21-Issue-8

MAJOR SUPPORTERS IN 2020/2021

A

Arts and Humanities Research Council, UKRI
Association for Innovation, Research and Technology Organisations (AIRTO)
AstraZeneca

B

Biotechnology and Biological Sciences Research Council, UKRI
BP International Ltd
BPE Solicitors LLP
British Academy
British Geological Survey
Brunel University London
BSI Group

C

Chartered Association of Building Engineers
Chartered Institute of Credit Management
Chartered Institute of Plumbing and Heating Engineering
Chartered Institution of Water and Environmental Management
Comino Foundation
Cranfield University

D

Defence and Security Accelerator
Defence Science and Technology Laboratory
Department of Health and Social Care

E

Economic and Social Research Council, UKRI
EIB Institute
Elsevier b.v.
Engineering and Physical Sciences Research Council, UKRI
ERA Foundation

G

Genomics England

H

Haskel Family Foundation
Heads of University Centres of Biomedical Science (HUCBMS)
Health and Safety Executive
High Value Manufacturing Catapult

I

Imperial College London
Innovate UK, UKRI
Institute of Biomedical Science
Institute of Materials, Minerals & Mining
Institute of Mathematics and its Applications
Institute of Quarrying
Institution of Chemical Engineers
Institution of Mechanical Engineers

J

Japan Society for the Promotion of Science
Johnson Matthey Plc

K

King's College London
Knowledge Transfer Network Limited

L

Leiden University

M

Make UK
McLaren Group Ltd
Medical Research Council, UKRI
Met Office

N

National Physical Laboratory
Natural Environment Research Council, UKRI
Natural History Museum
Nottingham Trent University

O

Open University

P

Parliamentary and Scientific Committee
Peter Jost Memorial Foundation

R

Research England, UKRI
Rolls-Royce
Royal Geographical Society (with the IBG)
Royal Society of Biology
Royal Society of Chemistry
Royal Statistical Society

S

Science and Technology Facilities Council, UKRI
Society of Operations Engineers
Sovcomflot (UK) Ltd

T

The Academy of Medical Sciences
The IET
The Medical Schools Council
The Royal Academy of Engineering
The Royal Commission for the Exhibition of 1851
The Royal Society

U

University College London
University of Birmingham
University of Dundee
University of East Anglia
University of Edinburgh
University of Glasgow
University of Hull
University of Kent
University of Leeds
University of Leicester
University of Nottingham
University of Plymouth
University of Reading
University of Sheffield
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W

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