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British Antarctic Survey research finds sea level rise set to increase

The West Antarctic Ice Sheet will continue to increase its rate of melting over the rest of the century, no matter how much we reduce fossil fuel use, according to British Antarctic Survey (BAS) research published in the journal *Nature Climate Change*. A substantial acceleration in ice melting likely cannot now be avoided, which implies that Antarctica's contribution to sea level rise could increase rapidly over the coming decades.

Scientists ran simulations on the UK's national supercomputer to investigate ocean-driven melting of the West Antarctic Ice Sheet: how much is unavoidable and must be adapted to, and how much melting the international community still has control over through reduction of greenhouse gas emissions.

Taking into account climate variability like El Niño, they found no significant difference between mid-range emissions scenarios and the most ambitious targets of the 2015 Paris Agreement. Even under a best-case scenario of 1.5°C global temperature rise, melting will increase three times faster than during the 20th century.

The West Antarctic Ice Sheet is losing ice and is Antarctica's largest contributor to sea-level rise. Previous modelling finds this loss could be driven by warming of the Southern Ocean, particularly the Amundsen Sea region. Collectively the West Antarctic Ice Sheet contains enough ice to raise global mean sea-level by up to five metres.

Around the world millions of people live near the coast and these communities will be greatly impacted by sea-level rise.

www.bas.ac.uk

UK launches AI Safety Institute

The UK's AI Safety Institute was launched on 2 November, the second day of a global conference at Bletchley Park bringing together AI nations, organisations and experts to discuss the global future of AI and work towards a shared understanding of risks.

After four months of building a team to evaluate the risks of frontier AI models, it has been confirmed that the Frontier AI Taskforce will now become the AI Safety Institute, with Ian Hogarth continuing as its Chair. The External Advisory Board for the Taskforce, made up of industry figures from national security to computer science, will now advise the new global hub.

The Institute will test new types of frontier AI before and after they are released, in order to address potentially harmful capabilities of AI models, including exploring all the risks, from social harms like bias and misinformation, to the most unlikely but extreme risk, such as humanity losing control of AI completely. In undertaking this research, the AI Safety Institute will look to work closely with the Alan Turing Institute, the national institute for data science and AI.

Already, the UK has agreed two partnerships: with the US AI Safety Institute, and with the Government of Singapore to collaborate on AI safety testing – two of the world's leading AI powers.

Astronomer Royal wins Copley Medal

Renowned astrophysicist and cosmologist, Martin Rees, has been named this year's recipient of the world's oldest and most prestigious scientific award. The Royal Society's Copley Medal, awarded for sustained, outstanding achievements in any field of science, was first awarded in 1731. Previous recipients have included Louis Pasteur, Dorothy Hodgkin, Albert Einstein, and Charles Darwin.

Lord Rees, a Fellow and former President of the Royal Society, and the UK's current Astronomer Royal, is one of the most distinguished theoretical astrophysicists of his generation and was chosen for his many and varied conceptual breakthroughs over several decades, with influence spreading far beyond the specialist academic community.

Lord Rees is also a member of the Council of the Foundation for Science and Technology.

New consortium to develop UK Biobank

Former CEO and Chairman of Google Eric Schmidt, and Ken Griffin, founder and CEO of Citadel and founder of Griffin Catalyst, have been announced as the first members of a new consortium that will shape the future of the UK Biobank, starting with £16 million funding matched by Government.

Their donations will support UK Biobank to grow its wealth of health data, to enable research unlocking the next steps in the understanding of health and disease. This could include using AI's ability to rapidly analyse large quantities of data to draw new insights from UK Biobank's data, such as in the analysis of cancer samples.

UK Biobank aims to be the world's most significant resource for health research, and is one of the country's important scientific assets. It is a database of in-depth genetic, health and lifestyle information from half a million UK volunteers, giving approved researchers worldwide access to an unparalleled source of data that is enabling medical breakthroughs, from treating cardiac disease to Alzheimer's.

WELLCOME COLLECTION

The more than £16 million ($20 million) being donated by Eric Schmidt and Ken Griffin will be matched by the Government, which will provide up to £25 million in funding in total for the UK Biobank, provided that an equal amount of private and philanthropic donations is also secured. The ultimate aim is to achieve at least £50 million in contributions for UK Biobank.

GUEST EDITORIAL

The announcement that the UK will finally associate to Horizon Europe marked the end of a long and drawn out period of deliberations following the UK's departure from the European Union.

Rebuilding international research collaboration

Adrian Smith

In September, an agreement was reached between the UK Government and the EU Commission enabling the UK to associate to Horizon Europe. It was close to three years after the principle of association for the UK was agreed as part of the Trade and Cooperation Agreement and over seven years since the UK voted to leave the EU.

It has taken a long time but throughout that period the research community has been steadfast in arguing the case for association. That was because of the value of the EU programmes – research programmes that have been built up over decades. The networks, collaborations and infrastructure that have been established would have been incredibly difficult to replace – Horizon Europe peer review draws on a pool of 30,000 experts from 34 countries. It was also because of the prestige and competitiveness of Horizon grants that attracts the best of UK scientific excellence and is a springboard to wider international collaboration. And it is one of the world's biggest programmes at around €95 billion over 7 years.

International collaborators

Science is global but Europe is the UK's largest and fastest-growing scientific collaborator in terms of co-authorship. Six out of the 10 strongest international collaborators of the UK are European countries with more than a third (33.5%) of UK research papers co-authored with other EU and associated countries, compared with 17.6% with the USA.

Given that we have now secured association, I am keen to look forward to how we make a success of the relationship, but it is also worth briefly reflecting on the damage done by delays. Despite the UKRI guarantee, we have still lost a significant number of good people who decided to take their grants elsewhere. The guarantee served a vital role in keeping funding flowing to UK-based researchers and maintaining a reasonable level of participation, with applications continuing to be submitted and reviewed. That reflected the commitment on both sides to keep the door open, a commitment whose importance should not be underestimated. However, applications have dropped and expertise in dealing with EU funding has been lost, so there is still recovery work to be done.

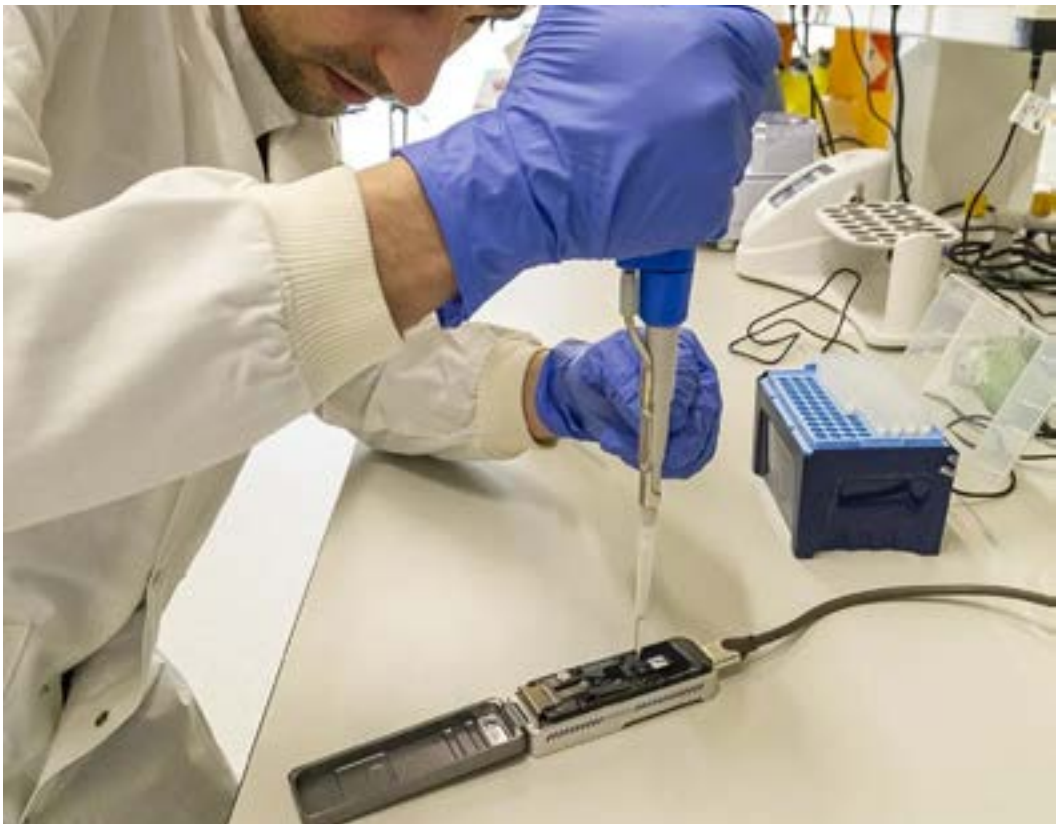
UK-based researchers have had to take a back seat on collaborations and that has harmed our leadership role. There was also the £1.6 billion allocated for association that was unspent over the past two years and which has been clawed back by the Treasury.

In the predecessor to Horizon Europe, Horizon 2020, the UK was a net beneficiary, securing 12.1% of the nearly €60 billion funding. The UK's science base is still incredibly strong and so we should be looking to hit the ground running on our full return to Horizon Europe. The UK must continue to be a magnet for people and ideas – and Horizon Europe can be a conduit for that. We all need to focus on the opportunities available and go out there and grasp them.

We will be supported in this effort by our colleagues across Europe. The support of researchers, research institutions and our sister academies across the Continent for UK association was immense and for that we are very grateful. That support was built on a desire to continue to work together. We must take full advantage of that and quickly rebuild any relationships and collaborations that may have suffered in recent years. Those doors will be open.

I think the main reason association was secured was the general recognition, on all sides, that it was a win-win, not just for the research community but for everyone. We all benefit from the progress that research brings. Cure rates for British children with leukaemia are being improved as a result of the IntReAll project involving researchers from Germany and the University of Manchester. Clean buses with zero emissions operate in London and Aberdeen thanks to the UK's participation in hydrogen fuel cell projects funded by the EU. Oxford Nanopore, an Oxford University spin-out 'unicorn' which

Sir Adrian Smith is the President of the Royal Society and previously served as Institute Director and Chief Executive of The Alan Turing Institute. He is a mathematician with expertise in Bayesian statistics. Adrian's comprehensive publications on diverse areas of Bayesian statistics have had a major impact on statistical practice in a wide range of disciplines and application areas. Between 2008-2012, he was Director General, Knowledge and Innovation in BIS (now BEIS) and has previously worked with the UK Higher Education Funding and Research Councils. Adrian is Chair of the Board of the Diamond Light Source and is also a board member of the UK Atomic Energy Authority.


QUADRAM INSTITUTE

A researcher using Oxford Nanopore's MinION device for genomic sequencing of the Covid-19 virus at the Quadram Institute, Norwich.

developed a new generation of DNA sequencing technology to monitor diseases and detect cancer owes many of its sequencing advances to the EU-funded international READNA consortium, which brought together researchers from 16 academic and industrial institutions.

This win-win has been long recognised but one of the challenges of getting association over the line was the value-for-money case. As I said before, in the predecessor to Horizon Europe the UK was a net beneficiary, securing 12.1% of the nearly €60 billion funding. The Government has accepted the value-for-money case and secured what it considers to be a good deal for the taxpayer – now UK researchers need to go out and prove it is a good deal by taking full advantage of the opportunities. We need that case to be well made in order to ease the process for associating to the next Framework Programme.

So association is secured and that is great news but there are still barriers to collaboration and the flow of people and ideas. Our expensive visa process sends the wrong message and we have to continue to make the case to Government of the need to be at least more competitive with other countries and at best to make it easier for the best talent to want to come to the UK ahead of other destinations.

The UK also needs to make clear that we have a long-term vision for putting research and innovation at the heart of our economy. We have great strengths, built up over decades, but with other countries looking to invest heavily to try and get ahead of us, we can take nothing for granted. The best way to attract talent and investment is to provide long-term stability.

Long term thinking will provide clarity on priorities, encouraging investment. It will create stable conditions to attract and retain the best talent. It will allow us to pursue the most ambitious research and commit to invest in research infrastructure.

Ongoing association to Horizon programmes is a great foundation but we can and should look to do more. Science is global and our worldwide collaborations and ability to attract talent must be too. There appears to be political consensus on the central role of research and innovation – as we head into a possible election year, we need to hear more from the parties on how they will scale up investment over a minimum ten-year timescale and create the right conditions for innovation to thrive.

The EU's research programmes have been of huge benefit to the UK and so association is a major victory. Now we have to move swiftly to capitalise on that victory, not just by securing funding and building collaborations across Europe but by using that as a springboard to ever-wider collaborations. That is how we will tackle the big global challenges and drive growth at home. □

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CONTEXT

The 2023 IPPC report notes that the planet has already warmed to 1.1 ˚C above preindustrial levels, and it is likely warming will exceed 1.5 ˚C this century. Current national plans are not sufficient to meet climate goals. Meanwhile, in the UK the Climate Change Committee's report of June 2023 suggests that the rate of emissions reduction in the UK is too slow, so hitting our own emissions targets will be very difficult. In addition, the Prime Minister announced a relaxation of some climate-related policies at the Conservative Party Conference in October.

To discuss the issues facing the UK and the world, and in advance of the COP28 Climate Conference in November 2023, the Foundation for Science and Technology organised a discussion on 11 October 2023. The speakers were: Lord Deben, Former Chair, Climate Change Committee; Professor Paul Monks, Chief Scientific Adviser, Department of Energy Security and Net Zero; Baroness Brown of Cambridge, Chair of the Adaptation Committee, Committee on Climate Change and Chair, House of Lord Science and Technology Committee; and Professor Jim Skea, Chair, Intergovernmental Panel on Climate Change. A video recording, presentation slides and speaker audio from the event are available on the FST website: **www.foundation.org.uk/Events/2023/Net-Zero-UK-and-global-progress**

Time to retake global leadership

John Gummer

SUMMARY

- The UK is failing to meet its statutory targets
- Creating fictional disadvantaged groups will not work
- Business wants stability and ambition not constant change
- The UK has led the world on climate change but that leadership is under threat
- Other countries see the opportunity even if we choose not to.

The latest report of the Climate Change Committee contained the sharpest language of any of them, because we felt it necessary to state plainly that the current Government is not on course to reach net zero by 2050. Nor is it on course to meet the targets it fixed for 2030. Any mathematician can see this.

Now the courts, under the Climate Change Act, had required the Government to explain how it was going to satisfy the statutory requirements. The Government provided a large amount of material in explanation which, unusually, they did not supply to us in advance. We received it on the day it was published. It took some time to read through the material, but by the end the conclusion was clear.

On a number of aspects we had previously given them the benefit of the doubt, but the documents showed very clearly there was no doubt. The fact is, the UK is not on course to deliver its commitments.

I have been in politics a long time. I recognise that we are probably within a year of a general election and people sometimes do silly things to try to create a divide between themselves and their opposition. In one election, Tony Blair was portrayed in a way that made him look like the devil: he manifestly was not an extremist, and it was not a successful campaign.

Now though we are faced with a Prime Minister who says that he will refuse to do a number of things. He says he is not going to have seven bins in every home – I know of nobody who has ever suggested that. He will not have a tax on meat – nobody has ever suggested that. So those things should not worry us.

What is worrying is the belief that somehow or other we can reach net zero without anybody being upset in any circumstances. There are groups of people who are invented specifically to be these disadvantaged individuals. One which is a favourite of some newspapers is 'the motorist'. I know of nobody who defines themselves as a motorist. It is an invented concept.

Put the date for EVs back to 2035 then – goes the claim – nobody need worry, because motorists can still buy secondhand cars which are not EVs and they can still sell cars that are not EVs. In fact, this is precisely what is already in place with the date at 2030. There is no change and, indeed, the demands on the industry remain the same.

Further, companies that had adapted to meet

The Rt Hon John Gummer, Lord Deben, is the founder and Chairman of Sancroft International, a consultancy that advises both businesses and investors on all areas of Sustainability and ESG (environmental, social and governance performance). Between 2012 and 2023 he was Chairman of the UK's Independent Climate Change Committee. Lord Deben was also the UK's longest serving Secretary of State for the Environment (1993-97) having previously been Minister of Agriculture, Fisheries, and Food.

DEAN CALMA / IAEA

COP26 in Glasgow: the UK urged global help for developing countries to achieve Net Zero cleanly.

existing Government targets were furious. The chairman of Ford said: "We want governments which have ambition and commitment, who stick to the things they believe and have said they will stick to." In other words, they need to have consistency, commitment and ambition. I am afraid we do not have a government which has any of those three in sufficient depth.

Yet, we should not think that a change of government would necessarily be different. When the Labour Party very rightly said it would not support long term further exploitation of the North Sea, the first organisations to attack the commitment were their two biggest donors, the GMB and Unite unions. It is a tough world, politically, to deliver net zero.

Politicians are much better at policy than delivery. Yet it is delivery that the Climate Change Committee has been pursuing. It is delivery that the courts are now considering, because this is a statutory requirement under the Climate Change Act.

Climate leadership

We ought to recognise the contribution this country has made towards global progress up to now, which is why the Climate Change Committee had to say that Britain has now ceased to be the leader. We set the targets the world has now begun to accept. We first committed ourselves to net zero in 2050. Meeting in Glasgow, it is the UK which said to the rest of the world, "We have to raise the money to help the developing countries to move from where they are to where they ought to be, without the intervening and damaging dirty stage."

We have every reason to be proud of our history, not least, the all-party agreement on climate change, invented by the Conservatives in opposition, which won over every other party and then the Labour Government. There are now 16 nations that are following us because they see it as the best available structure.

So my message is, first, that we have done more than anyone else. Secondly, we are resiling and that is both unconscionable and unacceptable. The third message is that we have to win back the momentum and that means winning the hearts and minds of people in Britain. The Daily Mail's motorist cannot determine how we proceed.

We have to bring climate change back into public debate and everyone has a part to play. Language is important: kilowatt-hours do not have the same impact as talk about bills. The whole of the nation must understand that this has to be fought now, immediately, with urgency. It has to be fought in a way where the UK leads the world instead of becoming tail-end Charlie.

The world is changing. The Americans have moved to a new place, the European Union has moved to a new place. China has announced the biggest move towards offshore wind, onshore wind and photovoltaics of any time in history. It will meet its targets and, crucially, it has turned that drive into a business. They know where the future lies. It is in the fight against climate change, and the battle to win the economic argument at the same time. □

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The road to 2050

Paul Monks

SUMMARY

- Achieving net zero is a complex challenge requiring a systems approach
- The UK was the first country to legislate for net zero
- Achieving the necessary reductions in emissions requires a combination of social, technical and economic measures
- Some sectors will be much harder to decarbonise than others
- Research and innovation will be critical to delivering net zero by 2050.

According to HL Mencken, "For every complex problem, there's an answer that is clear, simple and wrong." The challenge of net zero is a complex systems problem – and there are no simple answers.

The UK was the first country to legislate for net zero and is one of the few that still has mandatory legislative outcomes. In 2019, the Government increased the goal to 100% emissions reduction by 2050, compared to 1990 levels.

We work towards that goal through a series of carbon budgets set under the Climate Change Act. Carbon Budget 6 (CB6) has to be met by the mid-2030s. We are just beginning to think about CB7. The Climate Change Committee (CCC), as well as being the independent body that holds the Government to account, also links to the international process and the setting of Nationally Determined Contributions (NDCs).

Carbon Budget 6

CB6 set a goal of a 78% emissions reduction by 2037. The Government laid out the science and the policies to achieve that in the Net Zero Strategy that was published in 2021. The UK has a good track record globally with respect to decarbonisation: we have already achieved reductions of nearly 40% on 1990 levels. To meet the goal of net zero by 2050, though, we will require a greater rate of change.

The sector that has gone furthest in decarbonisation is power, with fuel supply second: other sectors such as transport and buildings have been much slower (Figure 1). And that gives a sense of where the challenges lie in the future. Electricity is a great story, renewables have grown strongly while the last coal station is about to be turned off – although we are still quite dependent on imported gas. Nuclear is an important part of the low carbon electricity mix.

Looking at the total amount of energy that we use, though, about 40% is used in transport, 40% in heating and only about 20% is accounted for by electricity. Much of the decarbonisation of the first two sectors will be through increased use of electricity. In fact, we will have to at least double electricity generation capacity by 2050. It will have to be low carbon and available 24 hours a day.

While technological change is required, success is also dependent on consumer behaviour change. This is a social problem as well as a technical one. Finance is also required. So this is a social, technical and economic problem. When we talk about this as a systems problem then, it is actually a system of systems problem in the UK and global context.

Green choices

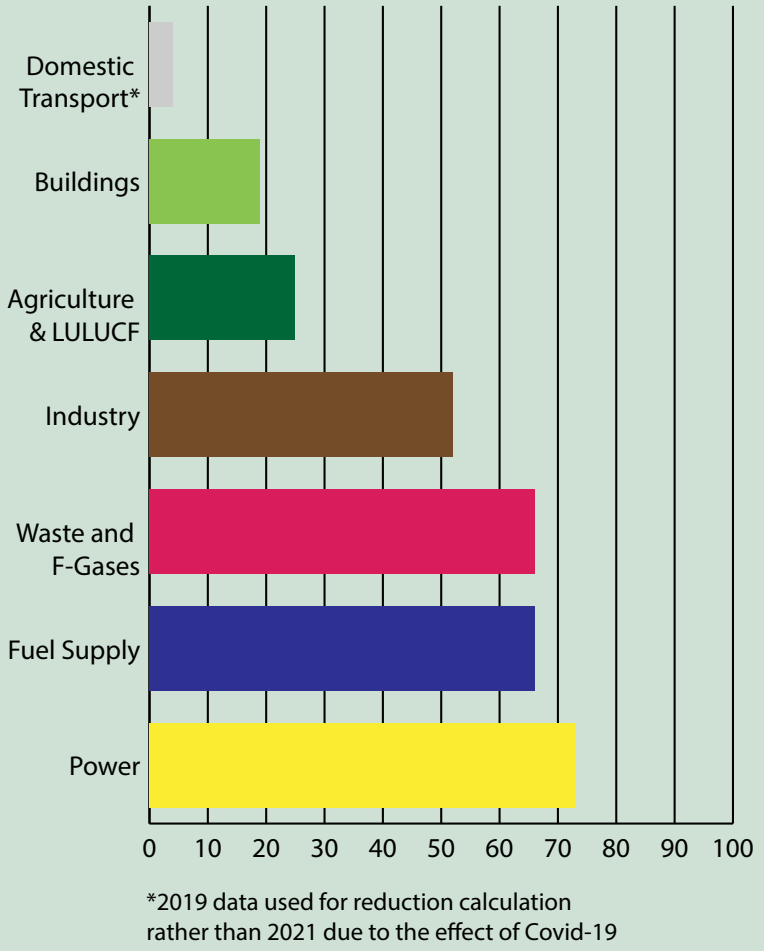
Under Carbon Budget 6, 44% of the required emissions savings require the public to make green choices (Figure 2). So it is unlikely the target can be achieved by a purely technocratic approach to net zero: there will have to be a socio-technical-economic approach. As part of that we will need to work out what the correct mixture of production, storage and uses are to achieve a net zero society. That will include the different flows within the energy system, including hydrogen, synthetic hydrocarbon fuels, and the like, the different ways of storing that and the different ways of using energy, in a way that creates a balanced system. Many people do not yet understand the way the energy system – and much else – will change by 2050. It will involve a fundamental shift, from very carbon-intensive, centralised generation to a low carbon, more distributed system. The net zero world will be very different.

Research and innovation

The International Energy Agency said recently that, on the journey to the 2030 target, we already have 80% of the technologies that we need. Looking at the hardest to decarbonise sectors and looking forward to 2050, a great deal of research and innovation is still required. The IEA estimates that the technologies needed to deliver almost half of the CO_2 reductions required are still in prototype phases.

Professor Paul Monks is the Chief Scientific Adviser (CSA) for the Department for Energy Security and Net Zero (DESNZ). As the CSA, he delivers independent and impartial scientific advice to Ministers and policy makers across the DESNZ portfolio. Paul also works closely with the Government Chief Scientific Adviser, other Departmental CSAs, and the Department's Chief Economist, to strengthen the links within and across departments, encouraging effective engagement and knowledge sharing, and to support delivery of a robust evidence base to underpin DESNZ policy decisions.

Figure 1. Sectoral reduction in emissions (%)



(Source: Department for Energy Security & Net Zero)

If net zero transition is to be sustainable and resilient, progress must be measurable, so that we can see the distance travelled. Deliverability is primarily an engineering challenge. We have the technologies to decarbonise the power system by 2035, but we have to roll them out. Part of that is a matter of scalability but there are some key science challenges as well.

These include hydrogen as well as carbon capture, use and storage (CCUS), and negative emissions (which people rarely talk about). There is the challenge of sourcing critical minerals as we move away from fossil fuel feedstocks to electrification. Resource and energy efficiency is an enormous problem that is continually overlooked. There are significant issues around agricultural emissions – this will be a very tricky sector to decarbonise.

Net zero is not just a mitigation problem, there is adaptation to address as well. This includes achieving the behaviour changes and green choices needed.

The Government has published its UK Net Zero Research & Innovation Framework, which takes a systems approach. It recognises that much of the decarbonisation programme is underpinned by digital technologies. The crucial role of finance is also detailed. And let us not forget the role of skills in delivering a sustainable net zero future.

Net zero is so pervasive through everything we do that only a systems approach will work. Research and innovation will be critical to delivering the outcomes that we need. □

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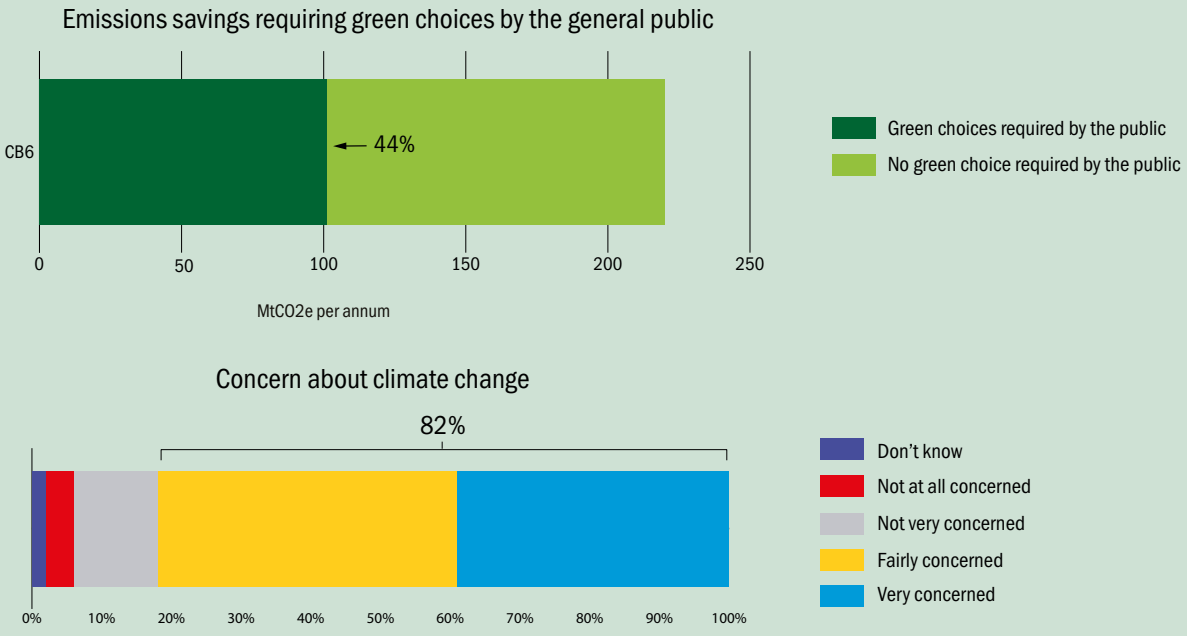
Figure 2. People are concerned about climate change and will need to take action themselves



(Source: Department for Energy Security & Net Zero)

Meeting our commitments

Julia King

SUMMARY

- Recent weather events demonstrate the urgency of action on climate change
- The rate of emissions reductions must increase sharply to meet statutory targets
- There is a real concern that the country is not planning for the long term
- Recent announcements have affected our international reputation
- Mitigation alone is not enough – we must work on adaptation as well.

The weather has been trying to tell us something. Last year in the UK, we experienced temperatures of over 40˚ C. Maximum temperatures in the South East of England are rising by something like 1˚ C per decade. Even more alarming is the fact that September 2023 was, globally, 1.75˚ C above pre-industrial levels – in contrast to the Paris target of staying below 1.5˚ C. 2023 is likely to be, on average, 1.4˚ C above pre-industrial and that is before El Niño has really got started. There should be a huge urgency about taking action on climate change.

As a result of the Climate Change Act, there are currently six legislated carbon budgets, which take us to 2037. We have met the first three, but not entirely by our own efforts. Meeting the first was made easier by the global financial crash, meeting the third was assisted by the impact of Covid.

Sharp rise

The primary factor driving our emissions reduction up to 2019 was decarbonising the electricity system. As we have emerged from the pandemic, emissions associated with some sectors – notably surface transport and aviation – have started to rise again sharply. We have seen a significant drop in emissions from residential buildings, although this was predominantly because the price of gas has increased dramatically due to the war in Ukraine.

Over the past eight years, the UK has been reducing emissions by about 3% a year. To meet the 2030 goal, that will have to increase to almost 6% a year. Much of the progress so far has come from decarbonising the electricity system, which has been relatively simple and people have not had to change their behaviour. Strip out the benefits of taking coal off the system and we have only been reducing emissions across the rest of the economy by a little more than 1% a year.

To reach the 2030 goal means reducing emissions around four times as fast. That will require engagement with people, a very strong focus from Government and some very effective policy delivery. Industry needs to more than double its rate of reducing emissions, surface transport needs to quadruple it. Buildings, fuel supply – these big emitters need to double the rate they have achieved to date. Industry, in particular, takes a long time to make investments to change major processes, so there is almost no time left to get the very significant change needed in our industrial processes.

The Net Zero Strategy was published in 2021. The Government was taken to court and the judgement handed down was that it needed to have a strategy where it was clearer how policy would deliver the emissions reductions. The Carbon Budget Delivery Plan was published early in 2023. There is a significant difference between the two documents in regard to surface transport – the contribution in the new plan is much lower. There are two contributors here.

First, the Government realised that the benefits of hybrid vehicles will be nothing like as strong as hoped. The emissions from plug-in hybrids will be significantly greater than expected. We should therefore move to fully-electric vehicles as quickly as possible.

The other factor is that the Government chose not to take any benefit from a potential reduction in driving. There has been a 5% reduction in kilometres-driven since Covid. However, it is not clear if this is a trend or something more temporary, so the Government has chosen not to take any account of that. Therefore, transport emissions in 2030 are projected to be significantly higher in the Government's new planning. Other areas will have to find additional reductions if the overall target is to be met.

The Climate Change Committee (CCC) has said it is confident the UK will meet the fourth carbon budget (CB4), the one for the mid-2020s. A major reason for that is actually that 5% drop in kilometres-driven. There is, however, much less confidence about CB5 (which is also our Nationally Determined Contribution under the UNFCCC) and CB6 due to be delivered in the mid-2030s.

There is a real anxiety that the country is not preparing for the longer term. Looking at the tar-

The Baroness Brown of Cambridge DBE FREng FRS, Julia King, is Chair of the Climate Change Committee's Adaptation Committee and Chair of the House of Lords Science and Technology Select Committee. She is an engineer and a Crossbench Member of the House of Lords. A career at Cambridge University and Rolls-Royce plc led to 10 years as Vice-Chancellor of Aston University in Birmingham. She led the 2007 King Review on decarbonising transport for UK Government and chaired the Cambridgeshire and Peterborough Independent Climate Commission.

Figure 1. CCC snapshot on progress to Carbon Budget 6

Surface transport	Energy supply	Buildings	Industry	Agriculture and land
Electric car sales	Grid storage	Electricity to gas price ratio	Bioenergy use in industry	Livestock numbers
Battery cell prices	Dispatchable low-carbon capacity in development	Greening Government Commitments	Electricity use in industry	Livestock exports
Petrol/diesel car intensity	Offshore wind	Low-carbon share of heat supply	Energy consumption per unit of GVA	Food waste
Petrol/diesel van intensity	Onshore wind	Energy efficiency measures	Private sector targets	Woodland management
Van km	Unabated gas	Heat pump installations	Industrial process emissions	Crop yields
HGV km	Refineries emissions	Heat pump costs	Hydrogen use in industry	New woodland
Electric van sales	Solar PV	Trained heat pump installers	Pipeline of hydrogen projects	Peatland restoration
Car km	Active demand response	Residential energy demand	Industrial energy efficiency	Anaerobic digestion uptake
Public charge points	Low-carbon hydrogen production	Non-residential energy demand	Pipeline of Industrial CCS projects	Energy crops
Public transport demand	Oil and gas production emissions	Non-residential buildings energy intensity	Industry consumption emissions	Meat consumption

Key:
- On track
- Slightly off-track
- Significantly off-track
- Too early to say
- Data not reported
- No benchmark or target

gets by sector, then surface transport and buildings are not on target, nor are industry or agriculture. The Government's policies and plans for energy supply are, though, more positive.

The CCC has developed a set of indicators it now uses to see whether we really are making progress (see Figure 1). Its assessment in June this year highlighted red flags in every one of those areas. So electric van sales are well behind where they need to be. As more deliveries are now made by van, van-kilometres have gone up significantly in the past few years. Heat pumps are a crucial technology but heat pump installations, heat pump costs, trained heat pump installers – all are lagging behind target.

There have been a number of developments since June when the last CCC report was published, including the Prime Minister's speech in September. While the push back of the petrol and diesel phase-out from 2030 to 2035 was not helpful, the zero emission mandate for car manufacturers is unchanged so there will not be very much difference.

There has been a number of delays to the dates when new gas boiler installations need to be phased out. Again, these will have relatively limited impact as they apply to special cases such as those who live off-grid and have a gas or oil tank in the garden. The increase in the boiler upgrade grant to £7,500 will be helpful.

The announcement in the Prime Minister's speech about fast-tracking grid infrastructure is hugely important because of the scale of electricity infrastructure we will need. However, the latest round of Contracts for Difference auctions – where there were no bids for offshore wind despite the UK's target for 50 gigawatts capacity by 2050 – is unfortunate, to say the least. Tata Steel's decision to switch the steelworks at Port Talbot to electric arc furnaces will improve the outlook for industry. The CCC has published an analysis of the impact of all these announcements, positive and negative.

The uncertainties caused by these announcements has, though, really damaged our international reputation. The investment in the electricity network over the coming decade has been estimated at between £50-60 billion per year. This country cannot find that level of investment on its own, we need foreign investment. Potential overseas investors now think the UK is backtracking on its commitments. And that is really damaging to our reputation. While that is probably an unintended consequence of the Prime Minister's speech, it may have the most lasting impact.

We must not forget, though, that while mitigation is critical, the temperature will keep rising at best for the next 30 years whatever we do. So mitigation alone is not enough. We need to adapt as well. □

DOI: 10.53289/KYKT6189

Urgent and ambitious action needed to tackle this challenge

Jim Skea

SUMMARY

- Greater action is urgently needed now
- We are not powerless, we have the means to effect change
- Without a focus on equity, the required consensus will not be achieved
- Equity – in terms of just transition – is relevant nationally as well as globally
- Net zero is not just about a date but also about cumulative emissions on the journey.

The global messages of the Intergovernmental Panel on Climate Change (IPCC) can be summarised under three headings: Urgency, Agency and Equity.

Urgency

Climate change is already upon us, we can see that plainly. In terms of emissions at a global level, we have bent the upward trend, but they have yet to start a downward path – and certainly not the steep downward path that we need to achieve net zero. Yet unless we get to net zero, global temperatures will continue to rise because of the cumulative nature of emissions.

Should warming go beyond 1.5˚ C, new risks will emerge: permafrost degradation; water scarcity in dry land areas; more extreme weather events; and potential damage to the productivity of food systems. Sea level rise, which is almost inevitable, is an existential threat for small island states and low-lying coastal areas.

Agency

Without immediate ambitious action, there are threats to planetary health and human systems. Now, that can easily turn into a message of despair. However, the IPCC has been very clear that we should not let the evidence provoke a sense of paralysis or lack of agency. We do have tools available, and if we deploy them we can avoid the worst impacts.

The world has already started to make progress on renewable energy – wind, solar, etc – and China has some of the biggest investments in all of these. On another front, the biggest deployment of electric vehicles globally is in China.

One thing that is clear, though, is the concentration of success in China, North America and Europe. There is a need to spread that more widely geographically, especially to developing countries such as in Sub-Saharan Africa, where much more investment in infrastructure is needed in order to enable the rollout of renewable energy.

In terms of successes, significant progress is being made on land-based measures, especially reforestation but also avoided-deforestation.

Significant progress is also being made on governance. We have the policy tools available to move us forward. More than 50% of global emissions are already covered by climate laws, policies and institutions. About a fifth of global emissions are covered by some kind of carbon pricing.

The tools are available then and there is enough money in the world – even though that means trillions of dollars – to deal with the challenge of climate change. But it means starting to get private sector funding to supplement funds from the public sector. So we have the technologies, we have the knowhow, we have the money – we just need to put them all to use.

A word of caution, though. So far, we have only achieved the easy wins. It may be a major engineering challenge to design and construct a 1GW offshore wind farm, but the really difficult challenge is to implement measures that involve changes to people's lives. The future challenges around transport, housing and diet will all be much more difficult.

Equity

Why should we be concerned about equity? Well, perhaps because it is simply the right thing to do. There is also, though, a pragmatic reason. Unless the actions we take are perceived to be fair, they will not gain the consent necessary for the transition to occur.

There are two dimensions to equity. One is the global perspective: equity between the global south and the global north. The last IPCC report set out the facts about the cumulative historical emissions of greenhouse gases and also the wide variation in per capita emissions in different parts

Professor Jim Skea CBE was elected IPCC Chair for the Seventh Assessment cycle in July 2023. He was Co-Chair of IPCC Working Group III for the 6th Assessment Cycle. From 2009 to 2023, Jim Skea was Professor of Sustainable Energy at Imperial College London. His research interests are in energy, climate change and technological innovation. He was Research Director of the UK Energy Research Centre 2004-12 and Director of the Policy Studies Institute 1998-2004. He has operated at the interface between research, policy-making and business throughout his career.

The IPCC has been very clear that we should not let the evidence provoke a sense of paralysis or lack of agency.


SHUTTERSTOCK/JENSON

China has made some of the biggest investments in renewable energy such as solar power.

of the world. Those who are most vulnerable to the effects of climate change are those who have contributed least to the problem.

That is why there are three interlocking goals within the Paris Agreement. There is the long-term temperature goal, but also goals on adaptation and finance. We cannot achieve where we want to go without taking account of the whole package.

The symbolism of commitments like the $100 billion from developed countries is incredibly important. Now, Loss & Damage will come up as an issue again at COP28.

Opportunity and risk

There is another dimension to equity, which pertains to national and sub-national perspectives. There are obviously big economic opportunities associated with a low carbon agenda, but also risks for those in declining sectors and the communities that host these economic activities.

There are also impacts on consumers. A feature of low-carbon transition is that it is capital intensive. You need to put money up front in order to lower the long-term costs. Who is going to pay for this will be absolutely critical.

At both the national and sub-national levels, how 'just transition' plays out for employers, employees and also consumers is important. But a transition that is perceived as just is a prerequisite for consent and effective change.

When discussing net zero, the first thing to note is that it is not solely a matter of the date when that occurs, but also the cumulative emissions incurred on the journey. The pathway matters. Delayed action means the world will be warmer than it otherwise would have been.

Reserves

Secondly, the reserves of fossil fuels in the ground would exceed the carbon budgets for the long term temperature goal in the Paris agreement if they were all burned. Some 80% of coal, 50% of gas, and 20% of oil current reserves need to stay in the ground to limit warming to 2˚ C – a very stark number. Therefore, any addition we make to reserves just creates more acute problems for future policymakers, who may have to choose between the economic revenues that they get from burning the fuels, versus actually meeting the Paris targets.

In summary, we are in a difficult and dangerous place and action is needed urgently. But we are not helpless, we have the agency to pursue our goals. Finally, paying attention to equity is essential if we are going to build the consensus to effectively combat climate change. □

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The debate

After the formal presentations, the speakers joined a panel to discuss points raised by the audience. Topics included: international standards; offsetting; global and unilateral actions; embedded emissions; energy security.

There are no international standards for net zero yet they will be essential. We are in urgent need of standards for green hydrogen that are consistent across different regions. There are many different products that people call sustainable aviation fuel and there needs to be much greater clarity on this. Britain has an interesting role here because we have a long history of standards development and implementation. There is an economic opportunity for us in this.

One contributor noted that if the UK had kept up with the code for sustainable homes there would already be more than a million homes at zero net carbon, where energy bills are measured in tens of pounds. To achieve net zero by 2050, we will have to offset. At the London Olympics, money was invested in energy efficiency measures and local schools. The schools used the money to employ special needs teachers. So is there scope for creating an offsetting fund that delivers carbon savings and societal benefits alongside?

Climate change is a 'global commons' problem, not one that will be solved by unilateral actions of individual countries. Unless there is solidarity between countries, the problem will not be satisfactorily addressed. So the UK has to be part of the solution, even if its emissions are not among the largest in global terms. Other countries are also making considerable progress: the efforts that have been made in China, for example, are very, very considerable.

WIKIMEDIA COMMONS/ SARAH & AUSTIN HOUGHTON-BIRD

London Olympics 2012: Energy saving initiatives

While much of the focus is on territorial emissions, attention also has to be paid to carbon embodied in trade. This has been coming down, partly because of reduced levels of global trade, but also because China, for example, a big exporting country, has made substantial improvements in efficiency.

Climate change is wrapped up in international considerations, including geopolitical tensions. Energy security and net zero are different sides of the same coin. The current geopolitical instability has made people think about indigenous energy generation, and that can only be good for the decarbonisation agenda, because much of that leads down the pathway of renewables. □

FURTHER INFORMATION

AR6 Synthesis Report: Climate Change 2023
www.ipcc.ch/report/sixth-assessment-report-cycle/

Net Zero Research & Innovation Framework
www.gov.uk/government/publications/net-zero-research-and-innovation-framework

Net Zero Strategy: Build Back Greener
www.gov.uk/government/publications/net-zero-strategy

The Climate Change Committee: Progress towards reaching Net Zero in the UK
www.theccc.org.uk/uk-action-on-climate-change/progress-snapshot

The Climate Change Committee's assessment of announcements by the Prime Minister at the Conservative Party Conference is available here:
www.theccc.org.uk/2023/10/12/ccc-assessment-of-recent-announcements-and-developments-on-net-zero

CONTEXT

The Government published its National Semiconductor Strategy in May 2023. It sets out plans to build on the UK's strengths in semiconductors in order to grow the sector, increase its resilience and protect the country's security.

On 24 May 2023, the Foundation for Science and Technology hosted a meeting at the Royal Society to explore the strategy and what it means for UK industry, both for silicon and compound semiconductors. Government Minister Paul Scully MP, Dr Andy Sellars from the Compound Semiconductor Catapult, David Clark of Clas-SiC Wafer Fab Ltd, and Dr Jalal Bagherli, the Co-Chair of the UK Semiconductor Advisory Panel, discussed how to ensure that the UK has a secure supply of the semiconductors it needs and the requirements for the UK semiconductor industry to thrive. A video recording, presentation slides and speaker audio can be found on the FST website at: **www.foundation.org.uk/Events/2023/TH-UK-Semiconductor-Strategy**

Securing the UK semiconductor industry

Paul Scully

Paul Scully MP is Parliamentary Under Secretary of State (Minister for Tech and the Digital Economy) at the Department for Science, Innovation and Technology. He is also Minister for London. He was previously Parliamentary Under Secretary of State at the Department for Digital, Culture, Media and Sport and before that Minister of State at the Department for Levelling Up, Housing and Communities. He is MP for Sutton and Cheam.

SUMMARY

- Semiconductors are at the heart of today's technologies and those of tomorrow
- The UK must understand both the opportunities and the risks involved
- The country is already strong in this sector, providing a platform for growth
- A key concern is to build supply chain resilience
- Cybersecurity is fundamental to protecting people and the economy.

The Government's aim is to become a science and technology superpower. That means growing a stronger and more innovative economy, with better jobs and embracing new discoveries which make a real difference to people's lives and livelihoods. The plan is ambitious, and one of the steps we are taking to deliver on those ambitions is our National Semiconductor Strategy.

Semiconductors are at the core of today's technologies but are also essential elements in our efforts to lead the world of tomorrow. New technologies will bring tangible benefits to British businesses as well as to people in every part of the country.

After crude oil, refined oil and coal, semiconductors are the most-traded products in the world. As the tech revolution picks up pace, they will matter more than ever. So, the National Semiconductor Strategy sets out a plan to enable the UK to stay at the forefront of that revolution by building a foundation on our core strengths in semiconductor technologies.

The opportunities are enormous but as we look to seize them, we must be clear about the risks too. Semiconductors are fundamental to many technologies which are critical for keeping people healthy and safe – from medical ventilators right through to fighter jets. Supply chains are vulnerable and hostile states may seek to acquire semiconductor technical advantage to the detriment of our national security.

In the face of those risks, this strategy is clear: we cannot and must not allow our economic and national security to be compromised. So the Government's vision, informed by and delivered with industry, aims to enable the UK to secure world-leading positions in the semiconductor technologies of the future. The strategy sets out three key objectives for delivering that ambition over the next 20 years: growing the UK sector by building on its strengths; making supply chains more resilient; and protecting our national security.

Growing the sector

The UK has enormous strengths in this field, from compound semiconductors to R&D, IP and chip design. The Government will focus on each of those areas of expertise where we have a strong foothold, enabling us to secure our position in the global market. Industry already receives extensive support, and this will continue. Going forward, the strategy will accelerate the creation of new companies and innovative new technologies.

Getting that support right starts with listening to businesses. They have said that the costs of

accessing critical equipment, infrastructure and skills are some of the most significant barriers to growth. This strategy will address these barriers, not solely through Government action, but through partnerships with industry and academia.

This strategy will deliver an investment of up to £200 million in 2023-25 with up to £1 billion in the next decade. The Government is also launching a UK Semiconductor Infrastructure Initiative, supporting businesses to access the software tools and manufacturing equipment that they need to design, prototype, pilot and produce innovations. This is about supporting businesses of all sizes, including our youngest businesses, our spinouts, startups and scale-ups. To do this, there will a pilot incubator programme, helping startup semiconductor companies in the UK access the tools they need to grow and thrive.

The Government will announce plans by the autumn to further support the competitiveness of the semiconductor manufacturing sector. Retaining that competitiveness starts, just as in any sector, with finding the right people with the right skills. That can be a challenge. Education is right at the heart of our Science and Technology Framework, with plans to improve STEM all the way from classrooms to graduate labs. This strategy also provides specific help for the sector through doctoral training to maximise opportunities for people and ensure the industry has highly-skilled people with the right qualifications for the job.

In developing the strategy, we listened to businesses, academics and leading figures in industry. To continue this process, we have created a Semiconductor Advisory Panel, bringing together key figures in order to shape the future of the sector in the UK.

Supply chain

To create a successful semiconductor sector and maintain that success in the future, we have to look beyond our borders. The second objective of the strategy is to build supply chain resilience and safeguard the UK against supply chain disruption.

The semiconductor supply chain is both global and complex, so no country can feasibly possess an end-to-end capability. We learned from the pandemic that shocks to the supply chain can and will happen. The UK will have to safeguard a reliable supply of semiconductors as best it can, including individual components and finished goods. That means decisive domestic action as well as international collaboration.

Working with suppliers to our critical industries (including critical national infrastructure) enables us to address and adjust to risks. At the same time, we are pursuing bilateral and multilateral engagement approaches to these shared challenges with like-minded nations such as the US, Europe and Japan.

SHUTTERSTOCK/HYWARDS

The Government is investing in new programmes such as Digital Security by Design to protect future innovations against cyberattacks.

Even while we remain open to international collaboration, however, we remain committed to doing all that is necessary to protect the UK against security risks associated with semiconductor technologies.

Protecting our security

The third objective of the strategy is to protect our people. So, we will continue to protect our most sensitive semiconductor companies and technologies from those that would jeopardise our national security. We have done so through the National Security and Investment Act, as well as through our export control regime.

In a world where technology is more and more connected, we need to be able to trust the devices we rely on, in our businesses, infrastructure and homes. So we are building on our existing experience in hardware security and investing in new programmes like Digital Security by Design, in order to secure the products of the future against cyberattacks.

This ambitious National Semiconductor Strategy represents the culmination of a collaboration between Government, industry, and academia. From growing the UK sector with the right infrastructure, skills and support for startups, to improving the resilience of our supply chains, and protecting our national security: we have a vision for the future.

The vision is different from those of other countries, but that is as it should be: it focusses on doing what is best for Britain. It concentrates on growing the economy, providing highly-skilled, well-paid jobs and boosting transformative tech. I am confident it will succeed. □

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Coordinating our activities with international partners

Andy Sellars

Dr Andy Sellars has led the Compound Semiconductor Applications Catapult since its inception in 2017. He chairs the Catapult Network Research and Technology Group and is a member of the Strategic Advisory Board of the EPSRC Future Compound Semiconductor Manufacturing Hub. Andy was appointed to the UK Government Semiconductor Advisory Panel, and he co-chairs the Semiconductor Expert Working Group for UKTIN. Andy joined the Catapult from Innovate UK, where he delivered £15 million of strategic investments in electronics, smart materials and compound semiconductors.

SUMMARY

- The modern economy depends on semiconductors
- Different countries are specialising in different aspects of the semiconductor supply chain
- The UK strategy needs to align and interact with our international partners
- The UK has a design capability across all the sub-sectors
- We need to coordinate activities across our existing clusters of excellence.

Industry requires access to semiconductors: without semiconductors, the economy will grind to a halt. There are three broad categories of semiconductor: silicon semiconductors (which predominantly run software); compound semiconductors; and the new category of 'emerging semiconductors'. Interestingly, the UK has strengths in all three domains.

A typical smartphone costing $1000 contains around $350 of semiconductors. The 'brain' running the software is a silicon chip, designed in the UK. The advanced functions, such as facial recognition, rely on compound semiconductors manufactured in the UK. The display is an organic LED – a type of 'emerging' semiconductor. So all three types of semiconductor appear in one product (see Figure 1).

Another example is an electric powertrain for automotive applications. Here, the compound semiconductor component is a very high proportion. Finally, a data centre has manufacturing costs of about $5,600 with silicon accounting for about 90% of semiconductor content. Compound semiconductors have quite a small proportion at the moment, but we expect that to change dramatically thanks to the work being carried out at Southampton University on silicon photonics.

Supply chain

What is the problem the National Semiconductor Strategy is trying to address? It is partly concerned with existing complex supply chains. Over the past 30 years, different countries have specialised in particular aspects of the value chain. Taiwan is the world's leader of silicon chip production. ASML in the Netherlands specialises in the production tools needed to make silicon semiconductors, while the UK and the US have focussed on the design and IP licensing of these products. In some ways, specialisation drives up productivity and drives down costs. Yet this happens at the expense of supply chain complexity and the risk that disruption can cause economic shocks exposing us to security risks.

No country can be self-sufficient in semiconductors – it is important to align UK activities and maximise our investment with international partners.

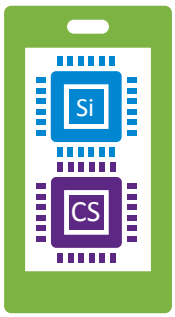
As no country can be self-sufficient in semiconductors, it is important to understand what other countries are doing, to align UK activities and maximise our investment with international partners. The US is investing $52 billion through the US CHIPS and Science Act, the EU Chips Act commits €43 billion, India has assigned $10 billion and China $143 billion. These big investments indicate the scale of the challenge across the globe.

Looking at the semiconductor supply chain, raw materials are used to make a wafer, then chemicals are etched into that wafer to make a die. The die is separated, and electrical contacts attached to make chips, which are assembled to form a system, with the system becoming part of an electric vehicle, a base station, a quantum device or a satellite, for example.

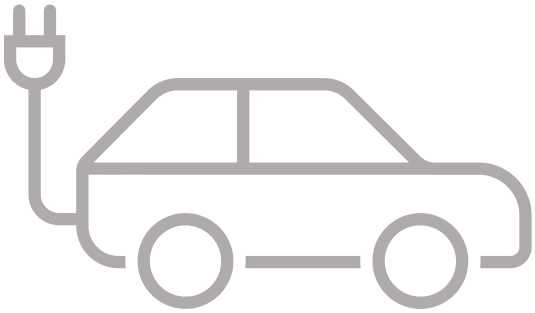
The UK has 25 fabrication plants: silicon fabrication, compound semiconductor fabrication, and emerging technology semiconductors. We also have about 20 packaging companies, representing the middle part of the supply chain, and then there are about 5,000 companies that design and manufacture electronic systems. For the size of the country, we are a reasonable player in this market.

The strategy refers to several semiconductor families: logic, memory, analogue and discrete. I have taken the liberty of adding another, large

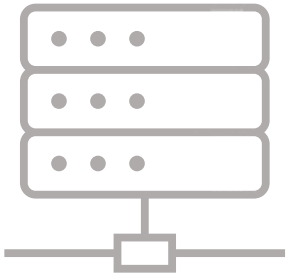
Figure 1. Semiconductor content in key technologies



Smart phone: $350
Silicon (Si) 80%
Compound (CS) 10%
Emerging 10%



Electric powertrain: $1,950
Silicon (Si) 20%
Compound (CS) 65%
Emerging 5%



Data centre: $5,600
Silicon (Si) 90%
Compound (CS) >5%
Emerging <5%

(Source: Catapult)

Value of semiconductors – and relative proportions of different types – in several key technologies.

area electronics. The UK has design capability in nearly all of these. We do not manufacture the most complex 'logic' family, they tend to be manufactured in Taiwan, but we still have world-leading design capability in this area.

The strategy also highlights the UK's excellent R&D in semiconductors, with an estimated £1 billion invested by the Research Councils and Innovate UK between 2006 and 2018.

The UK has excellent clusters of capability, and there is an opportunity to coordinate their activities to maximise our investments and build resilient supply chains.

R&D investment

Lastly, the Government has announced a Semiconductor Infrastructure Initiative. A contract has been awarded to the Institute for Manufacturing to carry out feasibility studies, looking at four infrastructure investments: silicon prototyping; advanced packaging; compound semiconductor open-foundry; and design IP. It is being funded by the Department for Science, Innovation and Technology. Cambridge Econometrics will build the evidence base for future interventions, with potential for an initial £200 million investment, setting out where that will make the maximum impact. □

DOI: 10.53289/KTAP8139

PEXELAS/SUZY HAZELWOOD

Focus on existing infrastructure will pay dividends

David Clark

David Clark is Chief Technology Officer at Clas-SiC Wafer Fab Ltd, a new 150mm semiconductor wafer fab, built in Lochgelly in Scotland. This is dedicated to the manufacture of silicon carbide power products such as SiC diodes and metal-oxide-semiconductor field-effect transistors (MOSFETs).

Clas-SiC Wafer Fab is an open, pure-play foundry that fabricates silicon carbide semiconductor devices. It carries out fast prototyping to aid the acceleration of R&D in areas such as net zero and the More Than Moore revolution. It has been very successful, seeing 500% revenue growth over the past year and doubling the number of customer accounts. We now have full 24/7 working with a consequent increase in headcount. The company is located in what used to be a coal mining area. In fabricating silicon carbide, we are still processing the carbon and silicon that used to be dug out of the ground in Lochgelly: so we have come full circle in a sense.

Media reaction to the launch of the National Semiconductor Strategy has not been very positive, concluding that £1 billion is not enough. Compared to the cost of a full TSMC-style wafer fab of £18 billion, it does not seem much. However, the Government strategy is concerned to "boost the UK's strengths and skills in design, R&D and compound semiconductors", not create TSMC wafer fabs here. Used wisely, the investment can make a significant difference. Compound semiconductor fabs, for example, do not need leading edge capability. Indeed, at Clas-SiC, we use technology developed several years ago, which is leading edge for silicon carbide, but not nearly as expensive as some other technologies.

So we believe that wisely targeted investment using existing infrastructure would be a prudent move. We believe that will build on the strengths of existing UK wafer fabs, quite a number of whom are poised to contribute to implementation of the strategy. It is important that any new infrastructure does not compete with these existing operations. Also, support for existing infrastructure could safeguard and potentially create jobs.

This type of investment could also allow businesses to hit the ground running. Drawing on the experience of Clas-SiC, it took five years from start-up to get a MOSFET field-effect transistor product approved and start production. All the time, there were customers waiting to make use of the facility. So, by building on existing infrastructure, companies can get a good start on their own programmes.

This approach also reduces risk. Things will go wrong, especially with constructing a new facility. We and other fabs have already navigated that level of risk. Clas-SiC started in 2017, we have spent £50 million and are now self-sufficient with proven technology. We have a healthy and growing customer base with demand for more.

SUMMARY

- The strategy is focussed on these skills and technologies where the UK has existing strengths
- Used wisely, the investment outlined in the strategy could make a significant difference to the sector
- A number of funding streams already exist
- Support for existing infrastructure offers reduced risk in expanding the sector
- Funds for scale-up are difficult to access.

Scaling up

The biggest challenge now is actually expanding and we need to find further funding. A small part of that £1 billion would help us to scale up as part of the Open Access infrastructure. Clas-SiC is not unique in this, it applies to many other semiconductor fabs and other sectors.

The funding climate in the UK at present is somewhat weighted against technology investments: funds are often more easily available in other international markets. So, wisely-targeted Government investment in existing semiconductor infrastructure will be most welcome and the £1 billion will go much further here than the initial press might have us believe.

The scale-up chasm remains a challenge. Government aspirations for the semiconductor industry are laudable and have brought us a good way. There are several existing R&D schemes managed by EPSRC, UKRI's Driving the Electric Revolution (DER) programme and the Advanced Propulsion Centre (APC), as well as other mid-Technology Readiness Level (TRL) programmes applicable to

The funding climate in the UK at present is weighted against technology investments: funds are more easily available in other international markets.

semiconductors. These are good schemes, taking projects through to initial production. But the UK seems to have a challenge in how to turn all that great science and technology into sustainable manufacturing jobs, ones which remain in the UK because too many of them end up going offshore. That needs to be tackled.

The Government is due to announce plans in the autumn that will include support for investment in the UK semiconductor manufacturing and for scale-up. We welcome that. However, there is a lack of clarity on how to enable scale-up. At the moment the road ahead seems a bit foggy and it is not actually quite clear how it all fits together and makes a difference.

It has, though, been good to see this initial £1 billion investment and the launch of the National Semiconductor Strategy. If it is implemented well, it could produce a win-win solution for industry and the Government. The existing R&D schemes work well but now we need to focus on how to resolve the problems beyond that initial stage, i.e. scale up. We will await with interest the next Government statement on this in the autumn. □

The existing R&D schemes work well but now we need to focus on how to scale up.

DOI: 10.53289/AZTH6298

Identifying the priorities

Jalal Bagherli

Dr Jalal Bagherli is Co-Chair of the UK Semiconductor Advisory Panel. He has over 30 years of experience in the semiconductor industry. He led Dialog Semiconductor from 2005 to 2021, ultimately leading the sale of the company to Japan's Renesas Electronic Corporation for €4.8 billion. Prior to joining Dialog Semiconductor, he held positions at Texas Instruments and Sony Semiconductor and became the CEO of multi-media processor start-up company, Alphamosaic. He is currently non-executive chair at PTSL Ltd and co-chair of the advisory board of Williams Advanced Engineering (WAE).

SUMMARY

- The strategy needs to focus on existing UK strengths
- Funding needs to focus more on the long term
- The strategy can provide a focus for the semiconductor sector
- While UK firms need to access the domestic market as a base, the semiconductor business is global
- Long term success depends on remaining connected to the global marketplace.

I want to reflect on my journey and the skills that have got me to where I am today. My journey started with university. I completed a four-year Masters in Materials Science at Manchester. It was during that university degree that I had an industrial placement and I think that was the pivotal part of my education.

When designing a strategy for the semiconductor industry, the key task is to determine what is important for the UK, what is specific to the UK that we can affect in a meaningful way, and how best to rally the industry around those aims. It is right that the policy focusses on UK strengths. We should not be pursuing areas where we have not been particularly strong or chasing technologies which are very capital-intensive to develop and take many years to build up a competitive position.

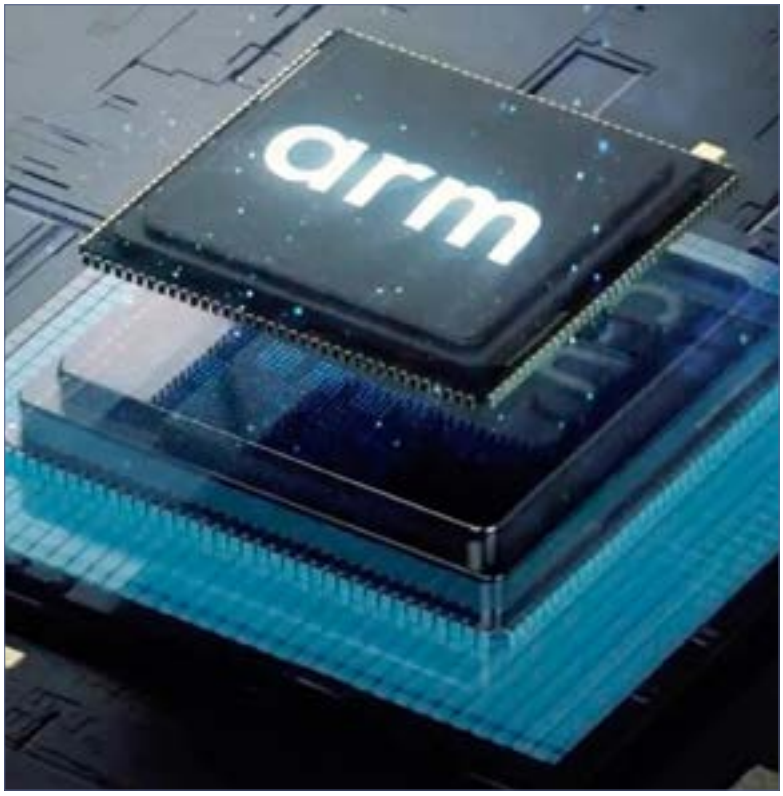
So the UK's key strengths, as set out in the policy, are in areas like R&D, design (of both products and systems), IP creation and IP business, as well as specialist manufacturing which includes compound semiconductors, photonics and thin film manufacturing. These are areas that have grown in the UK without help from the Government to date but we can now accelerate them.

Funding

Whether startups or publicly-listed companies, all businesses need funding: to start it, grow it and then later on, as it expands, to expand the operation or acquire other technologies. So funding is always a pinch point. Most startups have access to seed funding, but that is only a first step. Given the number of semiconductor startups in the UK, it does show that there is at least some funding available, but it is more difficult to take a company all the way through to commercial success through patient scale-up funding.

The funding environment in the UK is not tuned to long term investment. If some of the latest support initiatives that Government talks about can be unlocked, that will help UK deep-tech generally and semiconductors more specifically.

We also need to see the £1 billion funding semiconductor announcement as being supplemented by a number of other available funding streams in areas such as: netzero, electrification, green economy, digital economy, AI, supercomputing and space satellites, among others. There is what has been described as an 'alphabet soup' of various organisations that provide support to various technology sectors. A lot more collaboration would help to leverage more value out of these initiatives. Now, many of these areas are customers and users of semiconductor technology – indeed, without semiconductors, none can really succeed.



The UK has seen many key breakthroughs, including ARM and its licensing model, yet the industry is fragmented.

So, opening the door for British semiconductor companies to access those sectors, as a way to leverage the technology created in the UK, will provide a very good platform for our product companies to succeed. After all, that is what is wanted at the end: for UK semiconductor companies to succeed and grow their business worldwide. The UK market for chips by itself is just too small to sustain successful businesses. This is a global industry. So if you limit yourself to one small geographic area in terms of marketing and sales, that is not going to sustain long term growth. Growing beyond our domestic market will require additional funding support.

In the UK, historically, we have lacked a focal point for semiconductors. We have seen many key breakthroughs: ARM and its licensing model was invented here, Bluetooth single chip product was invented here, many other products that went on to achieve world success and become standard were created in the UK. Yet the industry is fragmented and giving it some point of focus is really important. Having a specific Government policy covering semiconductors is a welcome first step and so is creating some form of a national semiconductor institute that works on a consistent basis on our semiconductor strategy.

The City of London is particularly strong in areas like law and finance. In the semiconductor business, we do require better IP protection laws, scale-up finance, tax advice and business management training, all aspects of economic infrastructure that can help the semiconductor business.

International events

I would also like to see some UK-led conferences. I remember that, years ago, there would be major semiconductor conferences in the UK, but not anymore. Restarting these international events with support from Government could help the focus of the business and opportunities for building networks back in the UK.

Then, to thrive long term, we must remain globally connected, to markets, people and technologies, but also in remaining competitive on a broad scale. That is critical. Whatever the level of Government support, be it £1 billion or £10 billion, we as an industry cannot remain dependent on Government support forever. While this pump-priming initiative may provide an initial boost, success ultimately is down to industry leaders who create successful and competitive companies that can attract private sector institutional investments. □

DOI: 10.53289/OBXS4531

FST PODCASTS

Professor Rachel Oliver, Professor of Material Science at The University of Cambridge and Director of The Cambridge Centre for Gallium Nitride, tells us about the importance of semiconductors to industry and society.
www.foundation.org.uk/Podcasts/2023/Rachel-Oliver-Semiconductors

Scott White, Founder and Executive Director, Strategic Initiatives at Pragmatic, tells us about the company and their technology for making flexible, low cost transistors and chips.
www.foundation.org.uk/Podcasts/2023/Scott-White-Pragmatic-Semiconductor

Ian Croston, General Manager of Coherent, discusses the company's recent scale-up, challenges facing the field and what he would like to see in the government's strategy.
www.foundation.org.uk/Podcasts/2023/Ian-Croston-Coherent

The debate

Following the formal presentations, the speakers came together in a panel to respond to comments and questions from the audience. Topics included: EU and UK strategies; education; research; scale-up; and economy-wide challenges.

The EU and the US are looking to create a comprehensive silicon fabrication capability. The UK, on the other hand, is focussing on those elements where it already has market strength without trying to compete with those two.

The National Semiconductor Strategy suggests that the UK's STEM and skills programmes will result in areas of competitive advantage. In this country, universities are extremely good at research, and they are extremely good at producing graduates with relevant skills. If we do this correctly, we can develop a pipeline to bring these talented people into the industry.

There is £150,000 being invested in local schools on STEM initiatives, to help to supply engineers and technicians of the future. The industry has established graduate apprentices too.

Making a difference

£1 billion can make a difference if it is spent in a focussed way. In the past, the Government has concentrated much of its support on early stage research, but we also need continuity of support for our existing manufacturing facilities.

With new high growth compound technologies coming through, the country needs to be able to achieve a faster return on investment. A sovereign investment fund targeting semiconductor manufacturing would be very helpful in this regard, perhaps also some more focused technology-specific venture capital funds of the kind already seen with space technology.

The issue of scale-up is a key challenge for many industries include semiconductors. Yet the risks do not evaporate once a magic company size is achieved. They will need continuing support if the sector is to remain healthy and if all parts of it are to thrive. Back in the 1970s, we had some really big tech companies like Plessey, GEC and Ferranti who all had their own research centres as well. None of them survived. How can the country avoid repeating the mistakes of the Governments of that era who did not support our key domestic clubs industries at that time?

Some of the fundamental constraints that are holding back growth in this sector are not technology-specific. Instead, they are issues around planning restrictions, electricity grid capacity, fundamental skills and training that are required across manufacturing industry – as well as the sheer length of time it takes to get things done. □

FURTHER INFORMATION

National Semiconductor Strategy
www.gov.uk/government/publications/national-semiconductor-strategy

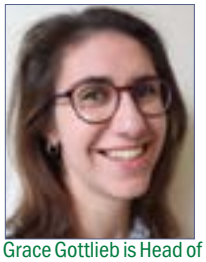
The semiconductor industry in the UK. BEIS Select Committee 2022
https://publications.parliament.uk/pa/cm5803/cmselect/cmbeis/291/report.html

The UK's International Technology Strategy
www.gov.uk/government/publications/uk-international-technology-strategy/the-uks-international-technology-strategy

CHIPS for America Outlines Vision for the National Semiconductor Technology Center
www.nist.gov/news-events/news/2023/04/chips-america-outlines-vision-national-semiconductor-technology-center

As the plans for the 2028 Research Excellence Framework take shape, the architects of REF and representatives from across the sector discussed their implications across two panel discussions

The emerging shape of the 2028 Research Excellence Framework



Grace Gottlieb is Head of Research Policy at UCL, where her work has focussed on areas including the financial sustainability of research, the regional distribution of R&D funding, transparency and reproducibility in research, and the intersection between research policy and research culture. In 2020 she was seconded to the Russell Group to lead a project on research culture. Prior to joining UCL, she worked at the Medical Research Council and Royal College of Surgeons.

What will the 2028 Research Excellence Framework (REF) mean for UK Higher Education Institutions (HEIs)? As a major mechanism for assessing and rewarding research quality and excellence – to the tune of £2 billion a year in Quality-Related (QR) funding and devolved equivalents allocated to institutions across the UK – there are few levers as influential as REF in shaping the value system underpinning UK research. Revisions to the REF have ramifications for institutions in terms of both prestige and funding, prompting both excitement and apprehension in the sector.

Positive change

It is no surprise therefore that the release of the initial plans for REF 2028 inspired rich discussion across two panel discussions at UCL on 5 July 2023, with representatives from across the sector. The excitement about REF's potential to effect positive change was evident from the Research England representatives speaking at the event, Dame Jessica Corner, Executive Chair of Research England, and Dr Steven Hill, Director of Research. As Dame Jessica reflected on the evolution of research assessment over the decades, she deemed REF 2028 "a once-in-a-generation moment when we have the opportunity to shift in direction". Indeed, she sees potential for REF to tackle major challenges in the sector, from the 'publish or perish' culture and lack of research reproducibility to the need to promote diversity and collaboration and broaden what research excellence means.

As described by Professor Geraint Rees, UCL Vice-Provost (Research, Innovation and Global Engagement) in his opening remarks to the event, one of the key shifts in REF is the reduction of the weighting of research outputs to 45-50%, alongside an increased focus on research culture, with a 'People, Culture and Environment' (PCE) element weighted at 25%. This is a notable shift – and a major incentive for universities to promote positive research cultures – that has been welcomed by some in the sector and challenged by others. A key question, noted Professor Rees, will be whether we have robust metrics to assess culture.

Dr Hill acknowledged that there is still a lot of work to do to develop indicators of research culture. Indeed, following the event, in October 2023, the funding bodies launched a tender for work to develop outcome-focussed indicators for the PCE assessment, alongside a consultation on the challenges and opportunities in this area. So how might one approach developing such robust measures?

Pragmatism

At the event, Sir Peter Gluckman, Chair of the International Advisory Group to the Future Research Assessment Programme, was pragmatic in his evaluation of how to do this. He pointed out that we are trying to be objective about something that is inherently subjective, as research quality, excellence and impact mean different things to different people. The goal, Sir Peter argued, is to find the best proxy measures and consider how accurate they need to be. Given that the measurement involved in REF drives conformity, he also questioned how we can maintain diversity, innovation and intellectual thought.

Another factor to consider is where the balance should sit between quantitative and qualitative metrics. Dr Elizabeth Gadd, Vice-Chair of the Coalition for Advancing Research Assessment (CoARA), described how CoARA favours qualitative evaluation, supported by responsible use of quantitative indicators. She also highlighted the risk of unintended consequences from new approaches and metrics, and the importance of listening to community feedback on proposed changes.

Diego Baptista, Wellcome's Head of Research Funding and Equity, also cautioned against unintended consequences, in particular for staff with protected characteristics, in the context of efforts to promote diversity in REF. As FST Chair, Lord Willetts pointed out that REF has a clear commitment to equality and diversity, and the impact of REF on EDI is a live topic under discussion. Recognising the need to get this right, Dr Baptista urged an iterative approach to assessment in REF.

Diversity is an important consideration not just with respect to staff but also to institutions. Dr Hill assured the meeting that the funding bodies

are cognisant of the need to strike a balance between culture metrics intended to make fair, consistent comparisons across institutions and the flexibility to recognise institutional diversity.

There is value in research culture indicators beyond REF, of course. Emma Todd, Director of Research Culture at UCL, described UCL's approach to promoting a healthy, inclusive research culture, through a 10-year roadmap for both top-down and grassroots change, drawing on academic expertise in behaviour change. As she pointed out, meaningful indicators are needed to know that the work we are doing is making a difference. While she argued that REF should not dictate work on research culture, the emphasis on culture in REF 2028 does help to sharpen the focus on how institutions are creating an enabling environment for research.

Institutional change

The potential impact of REF on individual institutions was evident from the story of how REF 2021 was used as a driver for change at Northumbria University. Professor Louise Bracken, Northumbria's Pro Vice-Chancellor (Research and Knowledge Exchange), explained how the university significantly increased the number of staff it submitted to REF 2021 and enjoyed success in its REF outcomes. With regard to the upcoming REF exercise, Professor Bracken acknowledged a mix of excitement and nervousness about the changes, including the decoupling of outputs from individuals.

This 'decoupling' means there will no longer be minimum and maximum requirements on individual staff to submit research outputs. This is part of a broader move away from focussing on individuals and towards institutions and 'team research'. This principle was welcomed by Professor Simon Hettrick, Chair of the Hidden REF, a competition to recognise the breadth of contributions to research. Hettrick sees decoupling as a good policy, but cautioned that its impact will depend on how it is implemented by HEIs. Decoupling has been criticised by some and Dr Hill recognised the risk that universities respond by focussing resources on a small portion of their research to maximise their REF scores.

As initial principles for REF 2028 are developed into more detailed plans, it is clear that many in the sector are deeply invested in the impacts they will have. As Professor Rees emphasised in his closing remarks, REF 2028 will need to straddle the numerous tensions that inevitably result from measuring something as complex as research excellence. There are tensions between qualitative and quantitative approaches, between the technical work that needs to be done and the limited time available, and between seeking the intended behaviour change without leading to 'game playing'.

SHUTTERSTOCK/ SOFIKOS

LOOKING TOWARDS 2028

On 5 July 2023, an event arranged jointly between the Foundation for Science and Technology, UCL and the Research on Research Institute, in association with Research England, provided one of the first opportunities to discuss and debate the plans with the architects of REF since their release.

The speakers were Professor Geraint Rees, Vice-Provost (Research, Innovation and Global Engagement), UCL; The Rt Hon the Lord Willetts, Chair, The Foundation for Science and Technology; Dame Jessica Corner, Executive Chair, Research England; Dr Steven Hill, Director of Research, Research England; Sir Peter Gluckman, Chair FRAP IAG; Dr Elizabeth Gadd, Vice-Chair, CoARA; Professor James Wilsdon, Director, Research on Research Institute, UCL; Professor Louise Bracken, Pro Vice-Chancellor (Research and Knowledge Exchange), Northumbria University; Diego Baptista, Head of Research Funding and Equity, Wellcome Trust; Professor Simon Hettrick, Chair, The Hidden REF; Emma Todd, Director of Research Culture, UCL.

A video recording of the event is available at: **www.foundation.org.uk/Events**

Opposing imperatives?

As Professor James Wilsdon, Director of Research on Research Institute, recognised, the REF sits alongside many other imperatives and drivers in the sector, some of which may act as obstacles to REF's agenda.

While there will be no perfect way to master these challenges, as REF takes shape, we must ask ourselves the final questions posed by Professor Wilsdon: How should we judge the success of REF? What would look different in the sector if REF 'works'? Whatever one's particular view on what that picture should look like, there is certainly potential for REF 2028 to bring positive change to university research cultures. □

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CONTEXT

Recent developments have shown the potential for Artificial Intelligence in the early detection of diseases such as cancer, Alzheimer's and retinal diseases. What is the current state of this technology in medical science? How widespread is its application? What will this mean for clinicians and patients? Are there particular ethical implications and how should the use of this rapidly evolving technology be regulated?

To explore these questions, the Foundation for Science and Technology brought together a number of specialists in this area at a meeting held at the Royal Society on 14 June 2023. The audience heard from David Crosby, Head of Prevention and Early Detection Research, Cancer Research UK; Mike Oldham, at the time Director of Early Detection of Neurodegenerative Diseases, Alzheimer's Research UK; Jessica Morley of the Oxford Internet Institute, University of Oxford; and Tobias Rijken, Co-Founder and Chief Technology Officer, Kheiron Medical Technologies. A video recording, presentation slides and speaker audio from the event can be found on the Foundation website at: **www.foundation.org.uk/Events/2023/The-use-of-AI-in-the-early-detection-of-disease**

The opportunities of using AI for early disease detection

David Crosby

David Crosby is Head of Prevention and Early Detection Research at Cancer Research UK (CRUK). Previously, at the Medical Research Council, he oversaw various science areas and research funding programmes (including inflammation, cardiovascular and respiratory research). He is now developing and implementing a new strategy and programme of research investments at CRUK which aims to accelerate progress towards earlier detection and prevention of cancer, through an integrated multidisciplinary approach, driven by equitable improvements in health outcomes.

The early detection of disease depends on three key issues. The first is who you test, which is a matter generally of understanding risk. The second is how do you test: that is a matter of technology. Then the third concerns what is one testing for and the nature of what has actually been found.

AI is set to have a major impact on all three of these domains, as it will in virtually every aspect of human life. What does it mean for the early detection of cancer? Aspects of scientific research and clinical care delivery are already being impacted by AI.

There is a great deal of evidence to show that AI and machine learning can be trained to replicate the function of, for example, a pathologist. When a biopsy of a potential tumour is taken today, a pathologist looks at a stained slide and makes a judgment about whether this is cancer or not. That judgment is based on pattern recognition: are they witnessing patterns of unusual cellular shape and behaviour. AI is, of course, a pattern recognition engine as is the human brain.

The machine can, in fact, be trained to essentially replicate the judgments that humans make. The problem with training the machine against human judgments as the gold standard is that it can then only be as good as the human judgments. The problem with human judgments, though, is that they are inherently flawed too. They can only perceive what they can perceive and so there is always the potential for small things to be missed or misinterpreted.

SUMMARY

- AI is a pattern recognition engine with many potential applications in early disease detection
- The hope is that AI can be trained to eliminate variability and subjectivity
- AI can potentially spot more complex, subtle and multifactorial patterns than a human can
- AI may be able to successfully integrate multiple streams of data into an integrated assessment
- There are important ethical issues in this subject.

There is also an issue of reproducibility between individuals: a different pathologist may look at the same image and give a different judgment to her colleague. Indeed, there is evidence in the literature of variability within individuals: a given radiologist at different moments of the day could make different judgments from the same scan.

Transcendence

The hope, then, is that machines will not just replicate human performance, but actually transcend it and eliminate variability and subjectivity. That applies to all image-based recognition areas whether reviewing an MRI scan, looking at pathology slides, or looking at images from an inside your lungs or colon. AI is already showing the potential to match human performance in these areas – and the hope is that it can exceed it.

Other technological advances will synergise with AI. For example, with early detection of colorectal cancer, the first test today is of the faeces to see if there is blood. If so, the patient is referred for a colonoscopy. A camera on a tube is inserted into the body and the data is interpreted visually by a human, who may or may not spot anything suspicious.

There are now technologies such as capsule endoscopy. The patient swallows a miniaturised camera in a pellet, that then passes down through the colon conducting continual video surveillance as it passes through. AI can be used to review hours of footage that would be extremely time-consuming for a human to carry out. A more complete picture then emerges with a combination of technologies.

Blood tests

Another advance is the multi-cancer, early detection blood test (MCED). Tumours are unstable, they break down and release their contents into the bloodstream. That tumour DNA is subtly different from normal, healthy DNA. But the fragments are so small and the concentrations so low that they are quite difficult to spot. Now, though, sequencing technology has advanced to the stage where this looks like a feasible method of early detection. And the advantage of blood tests is the ability to test for a number of different cancer types at the same time. In a given individual, one can be looking for lung cancer, brain cancer and colon cancer all at the same time.

There is a very large trial of one such technology happening in the NHS right now. That technology has been evolving over the past 10 years or so. It originally came from looking at foetal genomic aberrations. The traditional test for Downs syndrome is ultrasound followed by an amniocentesis. That has now been superseded, because fragments of foetal DNA float around the bloodstream.

So we have proof of principle but every cancer is different and every mutation is different. There are hundreds of thousands of permutations. Looking across all those different variations would be impossible for a human. But AI can search for those patterns – these MCED cancer blood tests are now feasible because machine learning has been employed to detect the optimal complex biomolecular signatures to search for and which may tell us not just that cancer is present, but where in the body it may be. That is a clear example where AI has jumped beyond what humans are capable of.

If it was known who was at elevated risk of developing cancer, or indeed any other disease, then we could be potentially much better at early detection. Any given disease is relatively rare in the general population. And tests are imperfect. If you tested everybody for cancer every year, there would be vastly more false positives than true positives. Now that is a problem with any testing or detection strategy.

One way of improving the detection rate is by only testing people who are at elevated risk. But how do we know who is at elevated risk?

One way of improving the detection rate is by only testing people who are at elevated risk. But how do we know who is at elevated risk? There are many areas of research where people are looking at different types of risk factor. Some people are interested in genomic risk of cancer, the genes you were born with which put you at different levels of risk. There are people who are interested in socio-economic determinants of health, which includes the environment you are born into, the pollution you grew up in and are exposed to day-by-day etc. Then there are people who are interested in behavioural risk: e.g. diet, exercise, tobacco smoke – all risk factors.

Now, AI might enable us to integrate all of these. That is a very complex proposition because it involves thousands of variables. Yet that is the hope: that AI will make a major impact in integrating multimodal data to assess who is at risk and who should be tested in the first place.

Impacts

So those are the three main areas where we will see significant impacts. One of the caveats, though, is that just finding something is not the end of the story. A great deal of disease can be inconsequential. Many prostate cancers are inconsequential, for example. They are growing so slowly that the individual will die of something else long before prostate cancer would do any harm. Equally, to build a machine that detected everything would generate a huge treatment burden on the NHS, which may or may not actually have any impact on anyone's quality of life or longevity.

Among other big caveats are stress and anxiety and their psychological ramifications. We have to think very carefully about what people want to know about risk and whether they have incipient disease, and whether we can really help them to lower that risk or prevent that disease. Those are important ethical considerations as we think about the future of AI in early detection. □

To build a machine that detected everything would generate a huge treatment burden on the NHS, which may or may not actually have any impact on anyone's quality of life or longevity.

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Finding the early signs of disease

Mike Oldham

Mike Oldham was Director of Early Detection of Neurodegenerative Diseases at Alzheimer's Research UK (ARUK) at the time of the meeting. Their programme involves harnessing the potential of digital technologies to collect a wide range of digital data to develop tools for detecting neurodegenerative diseases at their very earliest stage. Mike is an engineer who has spent his recent career working in innovation, helping new technologies make the difficult journey from research to industry.

SUMMARY

- One in three people will develop dementia
- Early detection and diagnosis are extremely important
- We need AI and machine learning to help detect the diseases that cause dementia
- AI can help clinicians pick up subtle patterns that are not easy to see
- We need sufficiently large datasets to avoid bias.

Dementia is one of the biggest health challenges of our generation. One in three people will go on to develop dementia: Alzheimer's disease accounts for about two thirds of those. During the next decade, we need to revolutionise the way we treat, diagnose and prevent dementia. First generation treatments, drugs that are intended to strip amyloid out of the brains of patients, are already showing positive, albeit quite modest, results, slowing down cognitive decline. There is light at the end of the tunnel. All the research, though, is pointing to the importance of early detection and diagnosis. If you cannot detect the disease, you cannot treat the disease.

Detection and diagnosis are different. Dementia is a set of symptoms caused by neurodegenerative diseases. Alzheimer's is the most common. Detection is the ability to determine the presence of that disease, the first changes that are happening in the brain. Diagnosis is when a clinician takes all of those facts and makes a clinical judgment about an individual. Someone once said to me that most dementias are diagnosed by accident, when there is an accident or a catastrophic trigger event. Then we ask what is causing it. In future, we will have to start diagnosing the diseases that cause dementia before the symptoms of dementia become apparent.

We do not need AI to diagnose dementia but we do need AI and machine learning to help detect the diseases that cause dementia. There are two complementary technologies employed at the moment in early detection. The first is pathology: amyloid and tau in the brain cause tangles which cause dementia, hence the latest drugs are focussed on stripping the amyloid out of the brain. Blood tests, PET scans and intrusive lumbar punctures are used to detect these proteins in the blood.

Cognitive functional testing is the other method in widespread use. This indicates when the brain is starting to change the way it works. The technique measures working memory, episodic memory, executive function, speech, language, etc. Genetic risk also needs to be considered.

We are on a journey from paper tests to digital to AI. For example, the clock test is a well-established tool: draw a circle, put the numbers on it, put the time in it. The first step is to replace the paper with keyboard or tablet entry. Then use AI and machine learning to reproduce what a good clinician can do. The next step will be to detect the patterns that are currently too subtle for the clinicians to spot.

We do not need AI to diagnose dementia but we do need AI and machine learning to help detect the diseases that cause dementia.

AI is also starting to support voice and language models, with the ability to analyse large amounts of data and extract relevant features. Cognitive impairment can be measured as speech and language change. Some of these tests are still in clinical trials, but looking to move into clinical use soon.

Meaningful measurement

As an engineer, the first question must be: can we measure clinically meaningful data? The ARUK EDoN Project, for example, has at its centre a really strong cognitive test measuring working and episodic memory, executive function, speed of information-processing, attention, speech and language. Can we make these tests more sensitive by adding data on things like gait, sleep, social activity, mood, eye movement, EEG, etc? Most people with relatives or friends with dementia will have seen all of these aspects change progressively and quite slowly. The challenge is to detect those subtle signs as early as possible.

We build the AI models using patient data in research cohorts; we start by plotting the time steps of somebody going into a clinic and having a series of scans, blood tests and memory tests. We then compare that with what the digital tests are telling us at the same time. The ultimate goal is to do away with the highly intrusive scans and testing and instead rely on the digital markers, identifying where people have a problem and then

PIXABAY / ROMAN GRAC

placing them back into the system. Ideally, we want to be able to carry out a series of tests on an individual and then supplement it with some sort of lifestyle tracking, in order to plot their trajectory of cognitive decline.

Another challenge is how to deal with the diversity of the population. Can these models really separate out the complex entanglements of geriatric depression and cognitive decline, people's education (particularly in early years education) and many other factors? There is a huge task in front of us.

Even if it were possible to tell an individual that they were on a particular trajectory, we would not act without understanding the pathology. Some drugs are very expensive and can have significant side effects. They would not be prescribed to somebody on the premise of just a digital test. The buildup of amyloid would need to be confirmed and one would want to know that the target was there in the pathology, in order to strip it out.

The biggest challenges, as ever, concern data and practicalities. First, what do you want to measure? Who do you want to measure that in? Who are the at-risk groups? Then we need a secure data platform to carry out all the harmonisation and the pseudomisation. All of those processes have to be completed before the data can be handed over to machine learning experts in order to extract all the meaningful clinical data. After that, how do you cascade this to a clinical audience in an explainable way?

Data is a real challenge. How much data is needed to build unbiased AI models? Many companies, particularly startups, are working with small datasets. Yet these risk inducing bias and we cannot afford to do that in dementia. Black and ethnic minorities, as well as women, are significantly more at risk of dementia than the general population and yet are under-represented in research. We cannot afford to make the biases any worse. That is why initiatives like the ADDI global data sharing platforms are enormously valuable in enabling a sufficient scaling-up the amount of data.

We are often asked if people really want to know if they are going to develop Alzheimer's dementia. According to our research, 74% of the population say they want an early diagnosis, with 38% saying they would like to know 15 years beforehand, so that they can plan and get things ready. It is so important that we get this right. Without appropriate regulation and appropriately trained models, people will go looking for answers in wellness apps and the dementia clinics will be clogged with the worried well.

We want to revolutionise the way we treat Alzheimer's. Early detection is key to that. AI and machine learning are the key to unlocking the power of early detection. Large amounts of well-characterised patient data are absolutely essential to build AI models that are unbiased and representative of the population. Patient data is where we need to start this journey. □

We are on a journey from paper tests to digital to AI. The first step is to replace the paper with keyboard or tablet entry. Then use AI to detect the patterns that are currently too subtle for clinicians to spot.

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How can we identify the contribution of AI?

Jess Morley

Jess Morley is a researcher at the University of Oxford. Her work focusses on the use of health data for research and analysis, including the development of AI-based clinical decision support software. She was the co-author of the Government-commissioned Goldacre Review of April 2022. Prior to working full-time in academia, Jess was a civil servant for the Department of Health and Social Care/NHSX.

SUMMARY

- Data permeates the healthcare system
- The NHS has not always been able to embed large scale technology transformation
- The NHS is committed to support innovations with potential to save lives
- AI has the potential to change the way the health service works
- AI cannot replicate the relationship between patient and clinician.

The Institute for Healthcare Improvement (IHI) Triple Aim for the NHS is to improve the population's health and improve the experience of care while reducing the per capita cost. This is to be achieved by 'P4' medicine; that is, medicine which is predictive, preventative, personalised, and participatory.

Essentially, this means gathering data on an individual all the time, using algorithms to find the level of personal risk and determining personalised risk stratification. Then the appropriate drugs are identified to provide personalised, earlier levels of intervention. This should reduce cost because it is cheaper to treat people early than late – or indeed to prevent people from getting sick in the first place. Ultimately, this should improve the population's health.

Data is at the heart of this concept. It permeates the healthcare system the entire time, not only improving our ability to diagnose individual patients earlier, but also improving our ability to record and monitor the overarching performance of the healthcare system and so deliver better outcomes.

Clinical decision support software (CDSS) has existed in the NHS since the 1980s. Further, the first paper promoting the idea that AI might help with diagnosing and diseases was published in 1959, so the concept has been known for a long time. CDSS is not very smart, though; it works on pop-ups based on flowcharts. If I go to my GP, for example, there will probably be a pop-up that appears in the electronic health record system to say: Jess is female, over 25, needs reminding to go to cervical screening. That is not very sophisticated.

More recently, there have been attempts to measure an individual's hazard ratios compared to different people in the population – i.e. compared to a baseline using large numbers of patient records – and predict the likelihood of adverse reactions to infection. In essence, these are models or algorithms predicting risk, which allow earlier intervention at the point of care.

The first paper promoting the idea that AI might help with diagnosing disease was published in 1959, so the concept has been known for a long time.

However, the NHS does not have a good record in large transformations of technology on this scale. The NHS National Programme for IT (NPfIT) was the biggest public sector IT transformation programme in the world. It cost a great deal of money and did not achieve its projected outcomes. However, it did deliver the NHS Spine which allows information to be shared securely across national services, a vital platform for the organisation.

A question of consent

Projects to do with data have also been unsuccessful. For example, the Royal Free and Deep Mind tried to develop an app called Streams, which would alert clinicians to people who were likely to get acute kidney injury. However, they misinterpreted data protection law. If the purpose is direct care, i.e. one doctor talking to another doctor, patient consent is not needed in order to transfer the records. If the purpose is research, patient consent is needed.

The Royal Free thought that because it was developing the app for use in the hospital, this fell under direct care, whereas in fact it fell under research. They had handed over many thousands of patient records without consent and had broken the law.

So should the NHS cease this activity? No, because the NHS constitution states that it is committed to supporting innovation when there is the potential to save lives. And we know that potential is there. But healthcare is complicated.

SHUTTERSTOCK/MONKEY BUSINESS IMAGES

Healthcare is as much about the dynamic between the patient and the clinician as the treatment itself. AIs cannot replicate that.

AI is complex, too. Remember, too, that we are not trying to deal with just one type of condition, we are trying to screen every individual for every possible condition at all times. Hardware does not always work, data quality issues can arise. Most of the population is not well-represented in our healthcare data.

The NHS is often presented as having the best healthcare data in the world. And we do, but it needs a lot of work to make it work, then it has to be integrated into clinical systems, you have to pass data protection requirements – and all of these stages have to go well for a project to succeed.

Re-ontologising means fundamentally transforming the healthcare service. AI has the potential to change what counts as knowledge about the body. This is because AI monitors things that we can record quantitatively – heart rate, how many steps a person takes, how much sleep they get. Yet it cannot measure how you feel and what your outcomes are. Often people go to the doctor when they just do not feel like themselves. That is an early indicator that AI cannot measure because it is not quantitative.

Should we only take account of what appears in the data, not what people say about themselves as a person? That would change who has the right to say that they have knowledge about the body – the algorithm or the person. In that case, we would only be considering the 'data clone' of an individual. That data clone may not accurately represent the person and their physical body.

We know that healthcare is as much about the dynamic between the patient and the clinician as the treatment itself. AIs cannot replicate that, they are not human. While it is possible to teach a Large Language Model to mimic an empathetic-sounding human, it will never understand what that actually means.

Treating everybody?

Not everybody is – or will become – equally represented in datasets. Not everybody has access to the latest smartphones. People who do not have a fixed address might not appear in electronic health records, although they are equally deserving of care.

Looking to a future where AI helps to prevent disease earlier, we should be focussing on aspects of information and utility. Does this application do something useful? Is it screening for something that we can actually treat? Is it usable – can the clinician actually run it in a clinic and understand what it says? Does it actually work – at the moment, AI is very precise and very accurate, but there is little evidence that it can improve outcomes in the real world. And, then, do people trust it?

If we can address those four things – utility, usability, efficacy and trust – we will have success. If we cannot, we will not. □

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Not everybody is equally represented in datasets. Not everybody has access to the latest smartphones.

Providing benefits for the whole population

Tobias Rijken

Tobias Rijken is the co-founder and CTO of Kheiron Medical, a leading developer of AI cancer diagnostics. Kheiron's breast screening solution is already helping doctors improve early breast cancer detection. Tobias has an MSc in Computational Statistics and Machine Learning from UCL with a Deep Learning focus. Before founding Kheiron, he was a Machine Learning scientist at BenevolentAI applying Deep Learning in the pharmaceutical industry.

Making sure that AI works for every woman everywhere in an unbiased way is key. If the AI is trained on biased data or a small dataset that is not representative of the general population, then it will not generalise.

Cancer detection and treatment raises a number of issues concerning information problems. Can we detect the cancer in the first place? How do we diagnose it and at what stage? What is the best treatment plan – and how should it be monitored to verify its efficacy? Then, when a person regains their health, the whole process must start again because the cancer can come back.

At Kheiron, we began at the start of the process, which is detection: you need to detect a cancer before you can do anything else. We focussed on breast cancer screening because it is one of the best-defined screening programmes we have today. Depending on the country, women between the ages of 50 and 75 are screened using mammography every two to three years.

Adding resource

To introduce AI into clinical workflow, the aim should be to keep everything else as much as possible the same but to help where there is a clear need. The problem for breast-cancer screening is the huge workforce crisis. The Royal College of Radiologists published a report recently in which they noted there is already a 29% shortfall in clinical radiology with 50% of vacancies remaining open for more than 12 months. The NHS is currently spending £223 million a year on overtime and outsourcing costs to address the shortage of radiologists. That is not sustainable.

This is where AI can help. The breast cancer task for radiologists is well defined: should we call back this woman back for further examination – yes or no? There is no diagnosis here: this is detection. Only 1% of women in the screened population have breast cancer, the other 99% are healthy. Maybe 10% of those are difficult to decide and those are the ones that matter.

How can we bring AI into the workflow in the simplest and most effective way? The Kheiron AI, called Mia, performs the same task as the radiologist, so it can be fitted into the process in a very flexible way (see Figure 1). On the top left is the current standard which is double reading. Every mammogram is read by two radiologists: when they agree with each other that is fine, when they disagree an arbitrator radiologist is called upon.

SUMMARY

- Breast cancer screening is a very well-defined programme
- AI can help meet a shortage of skilled clinicians
- Getting AI into clinical practice is not at all easy
- Generalisability is key to maximising the value of AI models
- Being able to monitor and adjust for change is critical to success.

This is incredibly wasteful in terms of resources because these two radiologists agree on the vast majority of cases. We want to reach a situation where Mia becomes one of those readers because that takes care of approximately 50% of all the reads in one go.

As another possibility, we have also identified that an additional arbitration step (see top right of Figure 1) can increase the cancer detection rate: we are seeing clinical evidence for this in Hungary. That does not reduce the current standard of care, there are still two human radiologists and also an arbitrator. This would just add Mia as an additional step to help identify some cancers earlier.

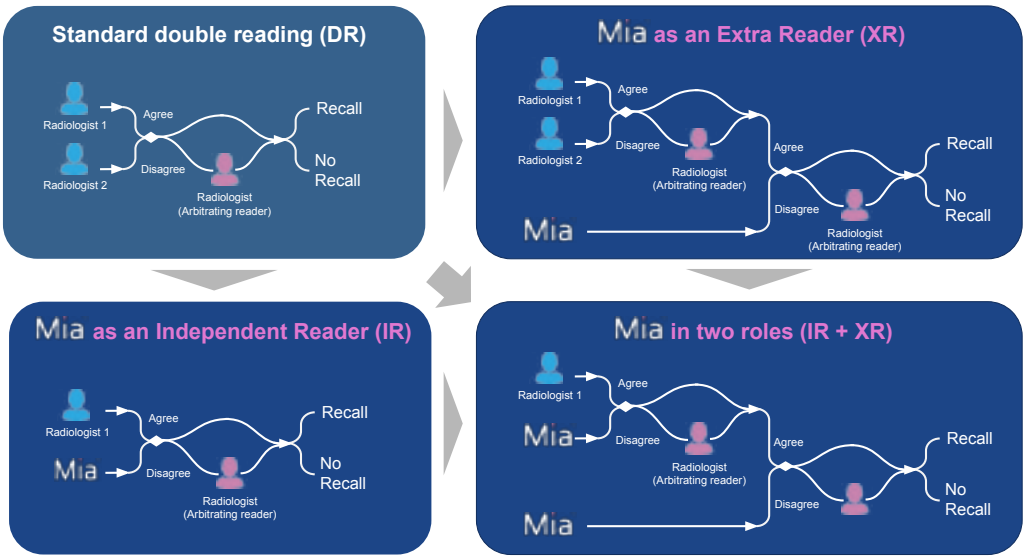
Clinical practice

Getting AI into clinical practice is not at all easy. Mia is already being used in Aberdeen as a service evaluation. Our Libra study is one of the first UK prospective studies and Mia is already being deployed in 15 screening units. By the end of 2023, we should be screening half a million women per year in the UK.

Generalisability is a key issue, making sure that AI works for every woman everywhere in an unbiased way. AI models are built on existing datasets but the aim is that it should work well on future data as well. If the AI is trained on biased data or a small dataset that is not representative of the general population, then it will not generalise.

To address this, Kheiron decided early on to build one of the largest – and most diverse – datasets in this field. Our data comes from the UK, Europe, Asia, South America and North America, incorporating different genetic makeups from

Figure 1. Options for incorporating AI into the breast-screening process



(Source: Kheiron Medical Technologies)

The Kheiron AI, called Mia, performs the same task as the radiologist, so it can be fitted into the process flexibly.

different hardware devices with different post-processing software, even different screening programmes. We demonstrated our results on a very large retrospective study of 275,000 cases.

The purpose is to build AI that works for every woman everywhere. One area of focus for us is breast density which is one of the risk factors. African American women have a slightly higher risk of being diagnosed with breast cancer and we are working with Emory University which has a large African American population. We are now testing how well the AI generalises and the results so far are looking good.

AI development is, however, just the beginning of the story. What happens next? AI and data are not stationary; indeed, data changes all the time. Those changes may affect how the AI performs. That is not necessarily a problem provided you monitor it and take appropriate action.

Early in the Covid pandemic, the NHS decided to stop screening for breast cancer. A couple of months later, when screening programmes reopened, we noticed that our AI started behaving differently, calling back more women – and it was not just us, the radiologists were doing the same. Now, that was completely natural because the cancers had more time to grow and the distribution had changed. The cancers were now bigger and we could detect that with our monitoring.

An AI system is more than just an AI model. It consists of the model itself, hardware to make the inference, but also modules that help determine whether this data is representative and if the outputs are along the lines expected. Other modules can help detect drift or bias – or the quality of the image.

As an example, one of our monitoring tools noticed that one hospital suddenly reported a completely different number of call-backs for women. It turned out the hardware vendor for this hospital had upgraded their post-processing software, but they had not told the radiologist or the hospital. We told the radiologist and were able to recalibrate the model quite quickly. Being able to detect changes to the data or the model in real time is absolutely critical to the safe deployment of AI.

Bringing AI into clinical practice is hard. There is no clear path to adoption at the moment. This is not just a technical problem to be solved, there are questions about who pays, who makes the decision about software in population-based screening programmes, etc – a series of challenges still to be addressed and resolved. □

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A recent report found there is a 29% shortfall in clinical radiology with 50% of vacancies remaining open for more than 12 months.

The debate

After the talks, the speakers joined a panel to discuss issues raised by the audience. These included: comparative advantage; the UK system, bias, regulation and standardisation.

AI is driven by applying enormous computing power to very large datasets and if the UK has any kind of comparative advantage it lies in our healthcare datasets. These will be of interest to the developers of AI.

The UK has substantial sets of longitudinal health records. It also has a large and very diverse population. However, much of this data is kept in legacy systems which may be difficult to access.

Practical issues

There are practical issues though. The data will already have some bias encoded, which has to be considered at the start of the data collection process. So for example, all the mammograms in the UK will come from women in a certain age range, because that's how we designed the screening programme.

The advantage the UK has is that we have a unified single system, a lifelong system, with an NHS number, patient identifier, and things can be tracked over time. However, the UK has managed to shoot itself in the foot several times over the issue of public trust. We did not engage with the public enough, before trying to implement these initiatives. So then there was a backlash with people opting out, withdrawing their consent for the data to be used for research. So public trust, communication, getting people on side is going to be the key to realising the potential of our health system as a data source.

There are major challenges about both regulation and standardisation for this field. However, the regulators are catching up and making major efforts to reconsider the way that they regard these technologies, how they classify them and how they evaluate them.

Pathway

What the country does not have yet is the established pathway we have for drugs, for example. There are clear thresholds and standards for evaluating whether the extent to which a new drug works is worth the money that it costs. There is a process. There is no such process for medical technologies, including AI, although there is a lot of work taking place to develop this.

But there will always be early adopters. Standardising the adoption of technology comes later. So there has to be some flexibility where early adoption and implementation are piloted in certain places as testbeds. □

FURTHER INFORMATION

Alzheimer's Research UK www.alzheimersresearchuk.org

Cancer Research UK www.cancerresearchuk.org

Institute for Healthcare Improvement Triple Aim www.ihi.org/Engage/Initiatives/TripleAim/Pages/default.aspx

Kheiron Medical Technologies www.kheironmed.com

NHS Spine https://digital.nhs.uk/services/spine

Royal College of Radiologists Workforce Census 2022 www.rcr.ac.uk/clinical-radiology/rcr-clinical-radiology-workforce-census-2022

Wellcome Trust https://wellcome.org

FST PODCASTS

The Use of AI in healthcare – Professor Chris Holmes, Programme Director for Health and Medical Sciences at the Alan Turing Institute
www.foundation.org.uk/Podcasts/2023/Professor-Chris-Holmes-The-Alan-Turing-Institute

CONTEXT

In March 2023, the House of Commons Science and Technology Select Committee launched its report on Diversity and Inclusion in STEM, which highlighted the important role Government can play in promoting and supporting EDI. The report came two years after the Government published the Research and Development People and Culture Strategy and in the intervening period a number of science and technology organisations and funders have reviewed Equity, Diversity and Inclusion (EDI) within their own organisations and across UK science and technology.

On 28 June 2023, at an event hosted between the Foundation for Science and Technology, the British Science Association and the Science Council, speakers from across the sector provided insights into this subject. The speakers were: Dr Lilian Hunt from The Wellcome Trust; Rachel Lambert-Forsyth of the British Pharmacological Society who is a Science Council Trustee; and Kevin Coutinho from the London School of Hygiene and Tropical Medicine, who is a British Science Association Trustee. A video recording, presentation slides and speaker audio from the event can be found on the Foundation website at: **www.foundation.org.uk/Events/2023/Equity,-Diversity-and-Inclusion-in-STEM**

Creating an environment for people to explore their potential

Lilian Hunt

SUMMARY

- Work to create greater equity, diversity and inclusion has been taking place for decades
- STEM is a creative activity and needs equity, diversity and inclusion to flourish
- Many of the initiatives in the area come from the grassroots
- The world of STEM reflects the imbalances of wider society
- EDI is a matter of social justice.

EDIS is a coalition of 29 organisations across the life science and health research sectors with shared commitments around Equity, Diversity and Inclusion (EDI), emphasising its importance as well as the need for senior leadership engagement and for collaboration.

It is important to note that this work is not new, it has been going on for decades, for example through Women in STEM and Black Women in STEM. There are reports that go back to the 1960s and 1970s, in the US, the UK and across the globe, providing recommendations that we would have expected to see taken up by the House of Commons Science and Technology Committee.

The Government's response to the committee's report talked about 'entrenched imbalances', which is really pale language. It does not address the fundamental problems of social injustice and inequalities. The committee itself has said that the response from Government was weak. I think the quote was: "It's a plan for a plan."

The inquiry

In 2018, there was a My Science Inquiry where the public were invited to put their requests to the Science and Technology Committee. Professor Rachel Oliver first submitted the suggestion for an inquiry into the impact of science funding policy on equality, diversity, inclusion and accessibility. The current inquiry is therefore the result of a grassroots push, and much of the work in this area is still coming from community activism and collaboration.

The APPG on Diversity in STEM, established with the British Science Association as secretariat, followed shortly after the My Science initiative. After the 2019 election, committees changed and the inquiry was shelved. In 2020, the APPG set up an inquiry into Equity in the STEM Workforce, which generated a brilliant piece of work that provided a foundation for the Science and Technology Committee inquiry launched in 2021.

Evidence was submitted to the inquiry from the public, from communities and from a range of organisations. Unfortunately, their suggestions have been weakened and diluted in the final report.

Dr Lilian Hunt is the Equality, Diversity & Inclusion in Science and Health (EDIS) Lead in Wellcome's Equity Diversity and Inclusion (EDI) team. They received their PhD in Genetics from UCL while at The Francis Crick Institute where they helped bring together the founders of EDIS in 2016. Lilian has since developed the coalition, supporting the 29 EDIS members to deliver on their EDI strategies covering inclusive research, culture and careers.

People believe that STEM is objective and that careers in STEM are structured in an objective way.

It is really important to note the balance of power in society – the systems, the structures, access to and distribution of knowledge, resources, history, culture. People do not see that these forces pervade STEM as well: they believe that STEM is objective and that careers in STEM are structured in an objective way.

We are all products of what has happened in our lives to date and the people we interact with – from role models to our families and the people we work with – as well as our own personalities. This influences the way we prioritise, the way we interpret situations, even the way we carry out research and innovation.

Diversity and inclusion are fundamental to harnessing creativity and STEM is a creative pursuit. The idea that we would exclude any group based on their identity or experience, or even prevent groups from expressing their creativity within the STEM workforce, does our entire country a disservice.

It is crucial that we keep making that case, because there are too many people who just do not see a problem.

There were some very disappointing parts of the inquiry itself. There was an MP suggesting that young women chose physics at a particular university because of a 'sexy professor'. Several people suggested that girls do not do physics because they are somehow conditioned not to like hard maths. There was an instance of a witness giving oral evidence being pressured to name and shame employers and leaders who were bullies – the committee did not consider the consequences for that individual.

There was disrespect for non-STEM subjects as well, by suggesting that STEM was more difficult and also more useful. Now, I am a geneticist myself, but I recognise that without the ability to interact with cultural and historical reference points, STEM tends to repeat the mistakes of the past in our methods and in our impact.

So the inquiry was not entirely smooth sailing, nor completely positive.

Social justice

One of points EDIS made was about social justice. This is about putting fairness at the heart of what we are doing here. This issue is not at root about business productivity, it is fundamentally about fairness. That is not just equality of opportunity, but also equality of outcomes, because the system has been so heavily weighted against some people for so long.

43% of researchers had experienced bullying or harassment while close to 70% had witnessed it.

If we see that there is significant under-representation, and that barriers exist for some people in the STEM research and innovation endeavour, we have to counter this not just by levelling the playing field, but through a more active rebalancing, at least for a while until you reach equality. I use the metaphor of rowing down a river. Stop rowing and the river will still carry you in the same direction as it has always done, so we have to actively row against the stream to get somewhere else.

The Government response to the committee's report has focussed on education: early years education and secondary education. Now these are really important stages on the journey. Yet the Government did not address the fact that science capital is built throughout a career, whether that is in research, in academia or in industry. Science capital is not just built on what you know but also who you know, where the opportunities are, engaging with people who fund your work or want to employ you. There are good reasons why Nobel Prize winners often have Nobel Prize winner parents and PhDs have PhD parents: it is because someone has told them how that system works, as well as the value and the benefit of it.

The Government response sets a 2030 target for a more diverse range of people to enter the science and technology workforce. 'Entering' the science and technology workforce does not mean staying, having a satisfying career and producing the best work. Further, it is not sufficient to just aim for 'more' diversity without any measurable targets.

Culture

People experience the culture within science and technology differently, for example there are varied opinions about the value of competitiveness. The Wellcome Trust's Research Culture Survey found that 43% of researchers had experienced bullying or harassment while close to 70% had witnessed it. Those numbers are shocking. There are targeted interventions across the whole of the sector that can improve the situation.

EDIS put forward a number of recommendations to the committee. The first was for investment in inclusive STEM education with a focus on building science capital at all stages, including beyond PhD stage. We asked for proactive steps to remove bias and ensure equal outcomes. We want support for organisations to create change and embed good practice. Legal frameworks need to be updated, there needs to be greater dissemination and uptake of guidance. We want investment in positive culture and incentives that reflect diverse contributions – and when we say invest, we mean money. Finally, we want consistency in the design, implementation and monitoring of EDI interventions. □

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Bringing the sector together

Rachel Lambert-Forsyth

SUMMARY

- To succeed there needs to be senior level commitment
- It needs to be effectively embedded in the organisation
- Social justice is a crucial element in the programme
- It is not just what we do but how we do it
- We need to make better use of data.

The Declaration on Equity, Diversity, and Inclusion (see box below) was developed by the Science Council with its membership in 2014. All members of the Science Council sign up to this when they join. It is designed to be an outward statement of their commitment to ensuring EDI is embedded across the organisation and can be used to drive commitment and action in this area.

In 2022, the Science Council's EDI steering group reviewed the Declaration and updated it. We updated the language, moving from a focus on 'equality' to one on 'equity', i.e. equality of outcomes.

Within it, there are four key elements. First, appoint a board level diversity champion. Their role is to work in partnership with the senior executive team to advocate for equity, diversity, and inclusion. This commitment must come from the top of the organisation and the appointed champion must have an interest, a passion and an enthusiasm for moving this work forward. Otherwise, it will never become embedded at the heart of the organisation and be a golden thread running through all programmes, projects, outcomes, decisions and processes.

Accountability

Such an appointment also ensures accountability at board level, and within the senior leadership team, improving practice and communicating what the EDI strategies are, so that staff and other stakeholders can get involved and contribute to progress.

The second area concerns planning and implementing an effective programme of work that will embed these aims in the organisation. The third is introducing measurement, assessment, and reflection on progress – and then of course reporting on those results. Data is crucial to support this process.

It is easy to state a commitment to increased and broader diversity but what does that really mean, especially if the baselines from which they start are not clear? It is not possible to know whether the commitment has made a real difference if continual measurement and reporting are not carried out using adequate levels of data.

To be effective, our commitment to measuring and reporting data must be renewed on a regular basis and maintained in between. The Science Council can help hold their members to account by asking them for data and encouraging them to show how they are improving.

The final element goes back to the convening opportunity within the Science Council. We want to share progress and learning across the sector. There is much that has already been done and is being done. We want to reduce duplication and bring together learnings so that everyone can share good practice.

Science capital

Science capital is often referred to in discussions about young people and the different stages of their careers. The work that has been carried out by Professor Louise Archer[1] can help organisations like the Science Council to understand how we can effect change in the system and so widen and increase participation in STEM long term.

The Science Council, in reviewing the Declaration in 2022, took the decision to change its language to ensure that equitable approaches are harnessed to deliver equality of outcomes. Our membership is broad with differences in size and resources, so it was not surprising there were challenges to that change of language. We have spent a lot of time working with the member

Rachel Lambert-Forsyth is Chief Executive of the British Pharmacological Society (BPS) and Managing Director of BPS Assessment Ltd (BPSA). Working closely with the BPS Council and senior leadership team, Rachel is responsible for delivering the vision, mission and strategy of the British Pharmacological Society, and its subsidiary companies. Prior to moving to the BPS in March 2020 she held the position of Director of Membership and Professional Affairs at the Royal Society of Biology. At the time of the session, she held the role of Diversity Champion on the Science Council Board of Trustees.

THE SCIENCE COUNCIL DECLARATION

By living the values of equity, diversity and inclusion, and critically assessing and acknowledging the inequalities that exist, the Science Council and its member bodies will create greater opportunity for any individual to fulfil their scientific potential, irrespective of their background or circumstances. In so doing it will also help science to better serve society by attracting the widest possible talent to the science workforce and fostering a greater diversity of scientific ideas, research and technology.

SHUTTERSTOCK / EVERETT COLLECTION

Despite all the investments that have been made, science and STEM have not moved away from the stereotype of the white, middle class, able-bodied man in a white coat.

organisations to understand how this change in language affects their practice, but there is still work to be done.

Social justice is then the next area of focus. Where are the barriers? How can we break down the structures that are maintaining those inequalities? There have been many efforts over the years to widen participation in STEM. So, how can these be brought together better? Where are the data that help us verify what is working and what is not? Data can identify projects that are not working or indeed might be detrimental to progress, and can identify programmes that are making a positive difference. Decisions can then be taken about where to use often limited resources, to further positive interventions and stop or change those interventions which are not working.

One point to note is that, despite all the investments that have been made, science and STEM mostly remain dominated by privileged people. By that, I mean white, male, middle class, able-bodied, non-neurodiverse, etc. That is especially true in subjects like engineering, physics, and computing, but not solely those subjects. Existing efforts often focus on expanding the young people coming in, rather than changing the system around them. This creates barriers to STEM and exacerbates inequalities.

If that is true, then the main issues are the systems (white supremacy, patriarchy, social class and ablism etc) and those practices that play a role in excluding and dissuading people from choosing and remaining in STEM and science. That is why this concept of social justice is important to progress further.

Yet it is not just what we do but the way we do it that is important. Approaching these discussions with kindness and understanding and an openness to other views is important. Often the underpinning values and mindset that pervade our organisations come from us. So, we must be more self-reflective and open to critical analysis of our own natural biases, in order to identify how this affects our decision making.

The Science Council's Progression Framework was developed in 2016 in collaboration with the Royal Academy of Engineering. It aimed to help professional bodies track and plan progress on diversity and inclusion.

We updated it together in 2020. It now sets out four levels of good practice across 10 areas of activity that professional institutions and scientific bodies encompass, from governance and education to outreach and metrics. It provides a framework within which to assess each of those functions – how we are doing, the areas where we need to invest more time or effort and those parts of the organisation where we are doing well.

Recently we have been reflecting on the impact of this framework and how we can make better use of longitudinal studies to gather the data to understand the process of change and the opportunities we have to make it more effective.

The Select Committee report highlighted the need for the sector to take a more systematic approach to EDI, making the STEM ecosystem a beacon of good practice when it comes to addressing underrepresentation. This is exactly what the Science Council has been trying to do for its own community. We are keen to work with the Government to grow this activity further. Some of the examples given in the report – around diversity in decision-making, various hiring practices, are a great challenge to the community. There are ways that the Science Council can convene and discuss these ideas further and we look forward to continuing to work with our members and the wider scientific community to ensure science really is for everybody. □

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[1] www.ucl.ac.uk/ioe/departments-and-centres/departments/education-practice-and-society/stem-participation-social-justice-research#sciencecapital

Building science capital throughout a lifetime

Kevin Coutinho

SUMMARY

- Change in this field can seem slow and not well-connected
- Science capital needs to be nurtured, supported and retained
- The challenge is to harness the many existing programmes
- Communities need our support in order to deliver their own science programmes
- We need more coordination, greater engagement and more effective leadership.

The British Science Association is on a journey towards equality, equity, diversity and inclusion: I use all four terms in the context of the UK, they all are relevant given our distinctive historical, legal and cultural experience. However, we are still discovering the destination that lies at the end of this journey.

We engage with many different communities but there are others where we do not have a connection and STEM is the poorer for it. I have worked in both Higher Education and the voluntary sector for the best part of 25 years. Change in these areas feels very slow and many of the initiatives do not seem very well-connected one with another. How can we engage the different communities within this sphere at a practical level? The Select Committee report has already highlighted some of the challenges facing the sector and some of the issues associated with it.

Initiatives

Among the British Science Association's initiatives are two that are very well-established. There is British Science Week and the CREST programme. In the Government response to the Select Committee report, we were pleased to see that both were mentioned. They are not, of course, the only initiatives in this area and we should all recognise the wealth of good practice already taking place. The challenge is to harness all of that in a way that leads to systemic change.

The CREST programme has been running since 1986, and each year over 50,000 young people take part. Science capital starts at a young age and, like any good investment, it needs to be nurtured, supported and retained. The problem here could be characterised as 'leaky pipelines'. These tend to focus on the water, not the infrastructure. Yet it is the infrastructure that provides support and retains the valuable contents passing through. While we see good numbers coming through our pipeline there is still some attrition. Retention and progression are not distributed equitably. That illustrates the importance and urgency of equity.

From the BSA's perspective, we need to identify what can we do to retain those people. So CREST is a really helpful example: we can work with students who are women, or from minority or socially disadvantaged backgrounds, in order to help them understand what problems they could face in STEM but then how they could engage with them practically to understand, address and solve them.

The programme has been attracting support from a range of different bodies. Students in different parts of the UK will have different experiences of it: the Welsh Government resources it so that every secondary school student in Wales can access it, for example.

Community engagement

The BSA is very invested in community engagement and there is a range of different initiatives which we support. Communities should lead their own science, bottom-up engagement, engagement with schools and indeed other parts of their locality. So we have a number of different programmes that we use to resource, support and partner communities.

A key element of our programmes is the evaluation we undertake. Through these evaluations, we come to understand to what extent the engagement we are building is diverse in terms of disability, mental health, age, race, and gender. More importantly, people see that these programmes are helping them increase their science capital and that, for us, is an important outcome.

The challenge is then to map out these different interventions so that we can create a pathway of referrals into different programmes and initia-

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Communities should lead their own science, bottom-up engagement, engagement with schools and indeed other parts of their locality.


GARRY KNIGHT

School pupils on strike in 2019 to protest about climate change.

tives. The issue of retention is one we deal with systematically.

Although specific Government responses may fall short of expectations, we do value the important role of interacting with and influencing policy. We provide the secretariat for the All-Party Parliamentary Group (APPG) on Diversity and Inclusion in STEM, which is chaired by Chi Onwurah MP.

We have also undertaken a number of research studies into public attitudes about these issues. One recent publication examined how climate change can be included in the curriculum. The British Science Association worked with the University of Plymouth to undertake a research project into understanding perceptions of teachers and students, bringing together the options for improvement. There is no quick fix to this because there are so many different stakeholders that need to be involved. Through our work, though, we better understand the challenges and the issues, identifying those individuals and bodies we need to influence and work with.

It is really important for us all to understand that representation does matter. If we walk into a room as a child and do not see the range of people that reflects our experience, and the profile does not change as we go through our education and employment journeys, it becomes a barrier preventing us from feeling that we belong. Such dissonance in STEM is problematic, for individuals, for the community and, indeed, for society.

Once we recognise that lack of diversity is a problem, we can also see that the response to date is disappointing. The necessary leadership has not been there, although in some ways that leadership has to be bottom-up. We have to recognise too that improvement will not happen in a straight line.

The Inquiry into Diversity and Inclusion in STEM is an important step on the journey. Now, we need to consider how we collectively nudge action in a direction that improves that diversity and inclusion.

Community engagement

There are today so many initiatives in this area. What we need is more coordination, greater engagement and leadership, and more clarity about what the data are saying. There is a great deal of data available, but specific datasets that help us, for example, understand the workforce are not readily accessible. Longitudinal workforce data becomes critical if we want to take this work forward and understand its impact on catalysing change.

The challenge is to provide sustained engagement from school right into retirement. Diversity and inclusion are not just an issue in entry level roles. Everybody has a role to play in providing that engagement. □

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The debate

The speakers joined a panel after the formal presentations to address questions from the audience. Topics included: Government involvement; timeframes; training; accountability; leadership.

Government focus tends to be driven by the four-year election cycle so there will always be limitations on its impact in areas that have a longer-term horizon. There is plenty of activity taking place without such support. However, much of this does cost money, often money upfront, with the benefits not being realised till much later. So Government support will be needed to make some of the big changes. On the other hand, there are some independent organisations, such as the Wellcome Trust, that are investing significant sums of money here.

There are some pockets of cultures that seem quite resistant to change. Even after implementing anti-harassment and unconscious bias training, some people with ingrained behaviours can act as a disincentive to new people to join. Perhaps external funders can exercise some influence over internal behaviours of organisations, requiring certain standards from organisations they are supporting.

Scarce talent

We are operating in a very tight labour market at the moment, there is a scarcity of talent. If organisations do not treat staff well, eventually they will walk. So the real challenge is to find ways to systematise better practice, making this accepted – and expected – behaviour. It is not just about the training.

Sometimes bright, young scientists just feel they do not belong. Statistics indicate that the higher up a person goes in these professions, the greater the problem. Yet, if people can see on news reports and in commercial publications, professionals from different backgrounds, they are more likely to feel that they can do that as well.

ISTOCK/FIZKES

People early in their careers often depend on an older professor, often a white male.

There is an issue about a power balance: very often people early in their careers depend on the support of an older professor – often white and male.

People need to be held accountable for not meeting expectations of behaviour or values. This is where many organisations fall down, because the consequences of not following through on the training are just not there.

People who are in senior research positions at the moment have not been promoted based on qualities like inclusive leadership or management skills. By and large, career progression is based on an individual's academic record, on the ability to do great research. So it does not include the kind of additional attributes like people skills, sponsorship, mentoring aspects. However, we are starting to see some of that change ❐

FURTHER INFORMATION

British Science Association
www.britishscienceassociation.org/edi

House of Commons Science and Technology Select Committee report: Diversity and inclusion in STEM (March 2023)
https://publications.parliament.uk/pa/cm5803/cmselect/cmsctech/95/summary.html

Science Council: Diversity and Inclusion Progression Framework 2.0
https://sciencecouncil.org/professional-bodies/equity-diversity-and-inclusion/diversity-framework

The R&D People and Culture Strategy (July 2021)
www.gov.uk/government/publications/research-and-development-rd-people-and-culture-strategy

VIEWPOINT

There have been a number of attempts to identify the right technologies for the Government to support. That selection will change over time and according to national and international political circumstances.

Which technologies will be key to the UK's future?

David Willetts

The Rt Hon Lord Willetts FRS HonFREng was appointed Chair of the Foundation for Science and Technology in December 2018. He is the President of the Resolution Foundation. He served as the Member of Parliament for Havant (1992-2015), as Minister for Universities and Science (2010-2014) and previously worked at HM Treasury and the No 10 Policy Unit. Lord Willetts is Chair of the UK Space Agency, and a visiting Professor at King's College, London. He serves on the Board of Darktrace, the Biotech Growth Trust and SynBioVen. He is an Honorary Fellow of Nuffield College, Oxford and a member of the Council of the University of Southampton.

Technology horizon-scanning is back in fashion – promoted by a renewed interest in its significance for national security and industrial capacity. We currently have five priority technologies. Before them there were seven technology families in the Innovation Strategy prepared after a very thorough consultation. My own contribution as Science Minister was the Eight Great Technologies which we launched in the Autumn of 2012.

I drew on technology horizon-scanning exercises by the Chief Scientific Adviser's office and by Innovate UK, distilling them down into a simple list which I explained in a pamphlet for Policy Exchange. The narrative behind it went roughly as follows:

"The digital revolution is the big technological advance of this century and we will invest in key applications where Britain has distinctive strengths and there are global business opportunities such as: AI and big data; Space and satellite data; and Robotics and autonomous systems. Those are the first three technologies. The greatest scientific discovery of the past 75 years, genetic code, itself comes in a digital form. The future is the interaction of dry digital technologies and the wet biological world. Britain has invented every major genetic sequencing technology and has a good regulatory regime for applying engineering techniques to genetics. We will invest in new technologies made possible by these advances, notably: genomics and synthetic biology; regenerative medicine; and agri-science – our three wet technologies. Yet none of this will happen without also investing in two key foundational technologies – storing low carbon energy to drive it and the advanced materials without which the kit and the sensors won't work."

I followed up with a pamphlet describing the Eight Great Technologies more fully. Instead of vague talk about Industrial Strategy it was intended to test specific propositions: that Government could successfully identify key general-purpose technologies and that it could back them on their way to successful commercialisation. 8GT would be a test case to assess whether the sceptics who doubt the value of these exercises were right or not. So my speech launching the pamphlet in 2013 invited the audience to "imagine that today we are burying a time capsule and we are going to open it up in 10 years when we take stock." So I have now published for Policy Exchange a review of how that exercise looks 10 years on.

By and large, identifying those eight has stood the test of time. Ten years on it is not a bad list. I hazarded some rather bold speculations such as "opportunities for the UK to host a space port if we get the regulatory framework right." Quantum had not quite registered then and came along soon afterwards – some called it the ninth technology. I underestimated how long the application of technologies such as self-driving cars or new battery technologies would take. Cell and gene therapies have done well, though I got the balance wrong and focussed more on the cell than the gene which is where the real action has been. It is a good example of the need for a bit of flexibility as a technology develops.

General to particular

Moving from general purpose technologies to particular companies is very difficult. In the original pamphlet I picked out one synthetic biology company as an example – Green Biologics, which tries to use engineering of biology to modify an organism so it makes key chemicals. I did, though, warn that after development of such an organism: "The next stage is just as tricky – the steps between an organism in a lab and a full-scale industrial process." Green Biologics closed down in 2019 and one report on its demise explained that the company never got to a full-scale industrial process. It is just one example of the difficulties of scaling-up, which is both a financial but also a technical challenge.

Since then there have been further attempts at identifying key technologies. The Government's

Innovation Strategy of 2021 listed seven key technology families:

- Advanced Materials and Manufacturing
- AI, Digital and Advanced Computing
- Bioinformatics and Genomics
- Engineering Biology
- Electronics, Photonics and Quantum
- Energy and Environment Technologies
- Robotics and Smart Machines

There are also now five key technologies which will be the focus of the new Department for Science, Innovation and Technology (DSIT):

- Quantum
- AI
- Engineering Biology
- Semiconductors
- Future Telecoms

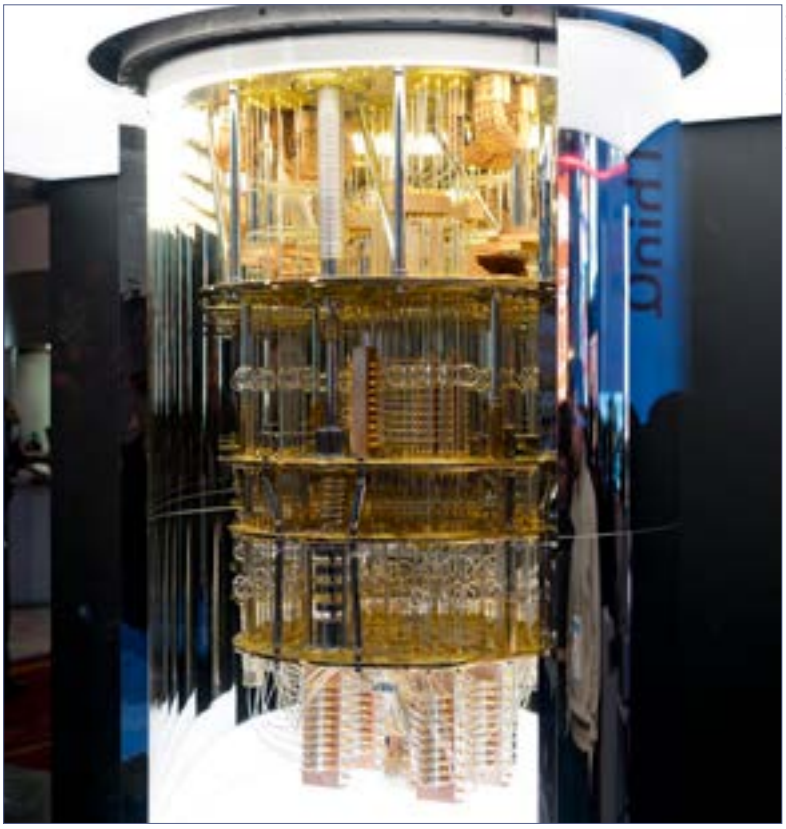
The National Security and Investment Act 2021 lists 17 key sectors and technologies where "Subject to certain criteria, you are legally required to tell the Government about acquisitions of certain entities." The list mixes together key technologies and sectors and indeed the responsibilities of entire Government Departments. It includes six of the original eight great technologies. It is a dramatic reversal of one of the tenets of Britain's free market model – an open market in company ownership. It reveals the biggest change in science and technology policy over the past 10 years which is the return of security issues to centre stage.

While BEIS had been prevaricating about any attempt to back key technologies and had run down the technology expertise of Innovate UK, the defence and security agencies were getting more and more focussed on them, partly influenced by the American model. A Cambridge tech entrepreneur put it very clearly when he asked me a few years ago: "How is it that the security services are so clear about the significance of my technology that they don't want me to have anything to do with Chinese investors but the Treasury and BEIS are so doubtful that anyone can possibly assess if this technology is of any value that they won't put in any British public support?"

Security

The new more turbulent global scene has brought security considerations to the fore. Scepticism about Industrial Strategy collapsed under the growing influence of the security and defence experts who set up and staff the Government's new Science and Technology Council. This is a really significant long-term shift of policy and it is a reminder that innovation is often driven by war and national security. The most important recent statement of industrial strategy is not from BEIS or DSIT. It is the Integrated Review of Security, Defence, Development and Foreign Policy published in 2021. It sets out a Strategic Framework with four objectives of which the first is:

"Sustaining strategic advantage through science and technology: we will incorporate S&T as an integral element of our national security and international policy, fortifying the position of the UK as a global S&T and responsible cyber power."



SHUTTERSTOCK/BOYKOV

The IBM Q System One Quantum Computer. Quantum arrived after the original Eight Technologies had been listed – some called it the ninth technology.

Challenges

The key security focus is on general-purpose technologies, many of which are potentially dual-use. This is different from the civil focus on Challenges. That model lay behind Greg Clark's Industrial Strategy of 2017 which had four challenges:

- Put the UK at the forefront of the artificial intelligence and data revolution
- Maximise the advantages for UK industry from the global shift to clean growth
- Become a world leader in shaping the future of mobility
- Harness the power of innovation to help meet the needs of an ageing society.

The Challenge is such a flexible concept that a technology like AI can be redefined as a challenge if that is where the funding is. But there are real challenges out there, of which the overwhelmingly most significant is the climate emergency. It

The application of technologies such as self-driving cars has taken longer than anticipated.

makes sense to set that challenge and then harness a range of technologies to tackle it.

I always enjoy discussing this issue with the charismatic Mariana Mazzucato who has made the case that Challenges should be part of the framework of innovation policy. They should be, yet they are not the whole story. Challenges can appeal to an anxiety regarding knowledge about real things by enabling policy to float above those key decisions. And they can be over-interpreted as meaning there is no need to invest in the underlying science and technology (which might give us the capacity to set future challenges). I co-chaired a Commission on the whole issue with Mariana and we agreed that there is a role for technology-push as well as Challenge-pull.

There is a role for Government too. New technologies and enterprises are on a long and tricky journey to the market. Easing some of the risks businesses face as they innovate is one of the best ways Government can promote growth. Government should not withdraw its support too soon and then expect commercial investors to take it on. It may hide its mistake by complaining that business leaders are risk averse but actually it is expecting them to take more risk than in many other countries.

This lesson is harder to learn because by the time there is an IPO and another unicorn floats on the Stock Exchange the original support from an Innovate UK programme may well have disappeared from view. Innovative companies usually only identify previous equity investments when they float. Non-dilutive funding such as Innovate UK grants are not part of the capital table so will not be visible, even to experienced investors coming in at that stage.

This promotes the illusion that all this 'just happens' because of savvy City investors with no public policy behind it. While bold, self-confident tech entrepreneurs and VC investors perform an invaluable role, they can understate the role of public agencies in getting these companies going in the first place.

Looking forward I am confident that there will be Government programmes to back key technologies. The issue now is the balance between backing them simply for their economic potential or whether the test today is whether there is a national requirement for them. We are still finding the right balance between the commercial and the security perspective. But without that security perspective, we would not have the attention and support which technologies now receive from Government. □

- *This article draws on the author's paper for Policy Exchange, 'The Eight Great Technologies 10 years On'*

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Grant Fitzner, Chief Economist, Office for National Statistics
Professor Jonathan Haskel, Professor of Economics, Imperial College

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Baroness Brown of Cambridge DBE FREng FRS, Chair of the Adaptation Committee, Committee on Climate Change and Chair, House of Lord Science and Technology Committee
Professor Jim Skea CBE, Chair, Intergovernmental Panel on Climate Change

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Professor Simon Hettrick, University of Southampton and Chair, The Hidden REF
Emma Todd, Director of Research Culture, University College London

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Dr Lilian Hunt, Equality, Diversity & Inclusion in Science and Health (EDIS) Lead, Wellcome Trust
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David Crosby, Head of Early Detection Research, Cancer Research UK
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The UK Semiconductor Strategy

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Paul Scully MP, Minister for Tech and the Digital Economy, Department for Science, Innovation & Technology
Dr Andy Sellars, Strategic Development Director, Compound Semiconductor Applications Catapult
David Clark, Chief Technology Officer, Clas-SiC Wafer Fab
Dr Jalal Bagherli, Former CEO, Dialog Semiconductor

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Phil Smith CBE FREng, Chairman of IQE, Chair of Digital Skills Partnership and former Chair and CEO of Cisco UK

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Sir Chris Whitty KCB FMedSci, Chief Medical Officer for England
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6 July 2022

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Sophie Macfarlane-Smith, Head of Customer Engagement, Rolls Royce SMR Ltd
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Naomi Weir, Programme Director – Innovation, Confederation of British Industry
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Dr Doug Parr, Chief Scientist, Greenpeace
Dr Hayaatun Sillem CBE, Chief Executive, Royal Academy of Engineering
Professor Melanie Welham, Executive Chair, BBSRC
Indro Mukerjee, Chief Executive, Innovate UK
Dr Peter Waggett, Director, IBM UK

The UK Innovation Strategy
13 October 2021

Rt Hon Kwasi Kwarteng MP, Secretary of State for Business, Energy and Industrial Strategy
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G

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J

Japan Society for the Promotion of Science

K

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L

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M

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N

National Centre for Universities and Business
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P

Parliamentary and Scientific Committee
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R

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Royal Society of Chemistry
Royal Statistical Society

S

Science and Technology Facilities Council, UKRI
Society of Maritime Studies
Society of Operations Engineers

T

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U

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