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Scotland sets out vision for innovation with strategy launch

The Scottish Government launched its 10-year National Innovation Strategy on 9 June (see *FST Journal* 23-4, p16). The strategy sets out a vision for Scotland to rank alongside Denmark, Norway and Finland in being recognised as one of the most innovative small countries in the world. It says that innovation and the ecosystem of businesses, organisations, universities and talent that promote and deliver it, will drive future national and regional economic success. Innovation is "a key tool to make Scotland a fairer, more equal, wealthier and greener country."

The document notes that: "We face challenges in maintaining our record of innovation in a rapidly changing, inter-connected world. While Scotland's

productivity and business investment in Research and Development (R&D) have seen significant improvements in recent years – with the gaps to the rest of the UK largely closed – we have work to do to catch up with our international competitors. Too few Scottish businesses are innovating, and some of our most innovative companies struggle to scale."

The strategy notes that Scotland has a competitive advantage and a strong research and business base in a number of key markets. These give rise to four broad innovation themes on which future activity will focus: Energy Transition; Health & Life Sciences; Data and Digital Technologies; and Advanced Manufacturing.

www.gov.scot/publications/scotlands-national-innovation-strategy

MRC funding now requires diversity

MRC will become the first UK research funder to require researchers to consider diversity when designing clinical and preclinical scientific experiments, it was announced at the end of June.

The new policy aims to ensure the Medical Research Council (MRC) research findings are relevant to and benefit everyone in society. It means that researchers funded by MRC will need to consider sex as well as other relevant characteristics when designing any research involving humans, animals, cells, and tissues.

In studies involving people, researchers should take into account whether characteristics such as sex, gender, age, ethnicity and socio-economic position are relevant.

Diversity and inclusion should also be part of developing public involvement and engagement activities to support research. Peer reviewers and MRC committee members will need to be mindful of these requirements when reviewing research proposals.

The policy builds on a requirement introduced in March 2022 when MRC announced that grant applications involving animal or in vitro research experiments must include both sexes as the default.

UKRI backs research on trustworthy AI

Universities across the UK are set to benefit from a £54 million investment in their work on AI. Delivered through UK Research and Innovation (UKRI), £31 million of the funding will be used to back research at the University of Southampton to establish responsible and trustworthy AI, bringing together the expertise of academia, business, and the wider public to explore how responsible AI can be developed and utilised, while considering its broader impact on wider society.

£8 million will be allocated to two Turing AI World Leading Researcher Fellowships, funding research on some of AI's biggest challenges including its application across drug and food design, and healthcare imaging.

£13 million will go to fund projects to help the UK meet its net zero targets. The projects will look at developing AI technologies to deliver more sustainable land management, accelerate energy efficient CO_2 capture, and improve resilience for natural hazards and extreme events.

Government updates geospatial strategy

On 15 June, the Government published an update to the UK's Geospatial Strategy looking at the latest trends and challenges impacting the geospatial ecosystem.

Geospatial applications and services have become a part of everyday life, enabling routine activities and improving individual consumer experiences from instant journey planners to faster delivery of goods. These services provide vital insights for businesses and the delivery of public services.

The potential of location data is enhanced by enabling technologies, such as artificial intelligence (AI) and cloud computing, which have caused disruption and opened up huge new capabilities, according to the Government. To make the most of these enabling technologies it will be essential to overcome limiting factors, such as a lack of awareness and skills.

The Government's renewed three missions aim to position the UK's long term direction towards the priorities of: driving technological innovation; realising benefits of applications of location data across the economy; and building confidence in the geospatial ecosystem. The actions described within these missions set out the first concrete steps towards these goals.

www.gov.uk/government/publications/uk-geospatial-strategy-2030/uk-geospatial-strategy-2030

GUEST EDITORIAL

The development of Artificial Intelligence systems has seen remarkable growth over recent months and years. Given the apparent all-pervading nature of these technologies, should the UK have a sovereign capability in this field?

A sovereign AI capability for the UK

Mark Girolami and Michael Wooldridge

SUMMARY

- An enormously successful new class of AI systems – Foundation Models – is causing profound changes in the technology sector
- Foundation models require enormous computational and data resources. Because of this they are currently the property of a small number of foreign-owned companies
- There are many arguments in favour of a sovereign AI capability in foundation models, and in part to address these, the Government set up a taskforce in April 2023
- There are many possibilities for a sovereign AI capability, ranging from a moonshot to develop UK foundation models from scratch, down to the simple licensing of technology.

We have seen a stream of advances in AI over the past decade, culminating in the release of ChatGPT in November 2022, which became the first mass-market general-purpose AI system. The success of ChatGPT is causing seismic changes in the big-tech industry: we are witnessing a technology watershed akin to the release of the World-Wide Web some 30 years ago.

ChatGPT is a Foundation Model – a very large AI system, built using vast quantities of data and requiring AI supercomputers to process that data. The resources required to build foundation models means that their development has been restricted to a small number of foreign-owned companies.

Ownership concerns

While there are many applications for this technology in the UK public sector which would bring significant productivity gains, currently this entails putting UK data on foreign-owned AI computers which raises many concerns. Additionally, reliance on foreign-owned companies raises concerns if the UK truly aspires to be a science and technology superpower: are we as a nation willing to accept that we will play no major part in the development of a technology as important as the World-Wide Web?

For these and other reasons, there has been much recent discussion around the possibility of the UK acquiring a sovereign AI capability in foundation models. Indeed, we have many existing organisations and assets well-placed to support such an endeavour, not least the UK's national institute for data science and AI – the Alan Turing Institute.

Against this background, the UK Governmnet made two important announcements in 2023. First, a £900 million investment in high-performance computer facilities for the UK was announced in the 2023 Spring Budget[1]. Second, on 24 April 2023, the Prime Minister announced the intention to form a UK Foundation Model Taskforce[2], with an initial budget of £100 million, with an emphasis on safe AI.

This article considers the question of what a sovereign AI capability for the UK might look like, what are the options, and what advantages and disadvantages do they have?

The main challenge for the UK is that foundation model technology is developed and owned by a small number of foreign-owned companies. For the most part these companies do not make program code or data open to inspection and they control access to their systems. The UK academic sector, while having historic strengths in AI, does not remotely have the resources required to build such models and UK universities are therefore greatly limited in the research they can do in this area.

This represents a serious national shortcoming if we indeed aspire to be a science superpower and believe that this technology represents a technological watershed. While the UK private sector has a flourishing AI culture, UK-owned companies cur-

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Professor Michael Wooldridge is a programme director for AI at the Alan Turing Institute and a Professor of Computer Science at the University of Oxford. He has been an AI researcher for more than 30 years. He is a Fellow of the Association for Computing Machinery (ACM), the Association for the Advancement of AI (AAAI), and the European Association for AI (EurAI). From 2014-16, he was President of the European Association for AI, and from 2015-17 he was President of the International Joint Conference on AI (IJCAI).

SHUTTERSTOCK / SOMYUZU

If a UK company develops a successful AI technology, then what is to stop it being acquired by a foreign body?

rently do not have experience in building foundation models, nor the capability to do so – although foreign-owned companies operating in the UK do have such capabilities (notably DeepMind).

A sovereign AI capability must involve establishing and sustaining an infrastructure around five different axes:

- People and skills. Researchers and developers with skills in foundation models are in high demand. A sovereign AI capability will require ensuring that the UK has a sustainable pipeline of such individuals, with skills ranging from understanding how to apply foundation models down to their scientific principles.
- Data. Foundation models require huge quantities of data. To obtain sufficient data, the standard approach is to download much of the World-Wide Web. This raises multiple issues: the web contains enormous quantities of biased and toxic content; and there is the very real possibility of poisoned data (i.e. bad actors deliberately seeding public data sources with disinformation). A sovereign AI capability thus requires trusted data with transparent provenance, reflecting UK values, including regulation (a subject that cannot be adequately covered in this piece).
- Hardware. Although the hardware issue might appear to have been resolved through the March 2023 Budget announcement of £900 million for UK compute, care will required to ensure that the compute resources that are ultimately procured through this are fit for purpose.
- Software. The open-source traditions of the international AI community mean that considerable quantities of relevant computer code are available. However, the scale of Large Language Models (LLMs) means that building a new model is a substantial (and expensive) software development challenge.
- Sovereignty. A sovereign AI capability must in some sense be owned by the UK. An extreme interpretation is that the UK controls the entire supply chain required to build such a model. This is not feasible for sovereign UK AI: for example, the UK does not have a suitable microprocessor fabrication capability. Any version of sovereign AI will involve some compromise against this standard. Purely private sector solutions are precarious in terms of sovereignty: if a UK company develops a successful AI technology, then what is to stop it being acquired by a foreign body? This suggests a sovereign AI capability would either have to be protected or else have a centre of gravity in the UK public sector.

Against this background, there are a range of models for a sovereign AI capability. Here are just

three, chosen to highlight some of the main choices and their implications.

1. Build from scratch

The most ambitious scenario would involve putting in place a major R&D effort to build a UK equivalent of ChatGPT from scratch. Irrespective of the involvement of public or private sectors, this would be a huge undertaking, beyond the £100 million envelope initially available to the taskforce. It would require putting in place an R&D team of something like 100 (highly paid) researchers and developers: just this staffing process would require a year even in the most optimistic scenario (more realistically 2-3 years to reach full capacity). It would require provisioning them with suitable computer resources (lead time 6-18 months if funding is no obstacle).

The team would need to acquire suitable datasets and put in place processes to address concerns, which would require coordination with (for example) defence and security partners – likely timescale at least a year, probably two. Once the team had all components in place (data, hardware, software), actually building a new foundation model takes months – and it is far from certain that the first attempt would succeed. The upshot is that the first new model would be 18 months from launch at least, even if funding was no obstacle, but the likelihood is that it would take much longer.

The chief benefit of this scenario is that, if successful, it would resolve the concerns listed above. Downstream, there would be licensing and other commercial opportunities available. Overall, the project would represent a decisive UK investment in this extremely important area.

There are of course risks – the most obvious being that the project simply fails. However, it is unlikely that a project like this would deliver nothing, and there would be significant national benefits in establishing capacity in this domain. A related possibility is that the project delivers something substantially behind the state of the art.

2. Adapt existing software to UK needs

A more modest scenario would involve negotiating with trusted private sector partners to build models using their software, using data we provide, running on secure UK data centres. Thus, we would not own the program code – but the models would be built to our specification, with our data, on our computers.

Ultimately, this would amount to the UK licensing technology, rather than developing it from scratch. However, we would play a role in the configuration of the software, working alongside tech companies while models are being built, and having some freedom to adapt the technology to UK needs.

What is clear is that we do not have the luxury of time to hold out for certainty – choices must be made now to keep the UK at the forefront.

This approach is less risky than the first scenario and surely less costly; it could likely be done within the £100 million envelope of the task force. The biggest risk would come in negotiating suitable arrangements with private sector providers – in particular, putting UK data on foreign data centres should not be considered acceptable. We note that the Prime Minister recently secured agreements with several big-tech companies to have preferential access to their foundation models, providing a starting point for negotiations.

Noting the requirement for a pipeline of skills, we again emphasise the important of R&D programmes supporting research around the applications of foundation models in the public sector.

3. Off-the-shelf solutions

The least risky solution would involve simply licensing technology from existing suppliers on suitable terms. The UK would play no part in developing the software and our expertise would in this case amount to nothing more than hosting it. R&D efforts would presumably be limited to finding applications of the technology in GOV.UK bodies.

Such a solution is low risk, but very low ambition. It would likely deliver productivity benefits in Government Departments, which would have the benefit of working with polished state-of-the-art products. However, it is hard to see how this could be considered as delivering a truly sovereign AI capability. Crucially, it does not satisfy the skills, data, or sovereignty requirements listed above: the UK would not 'own' the technology in any meaningful sense.

Each of these choices involves trade-offs. What is clear is that we do not have the luxury of time to hold out for certainty – choices must be made now to keep the UK at the forefront. □

Acknowledgement

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1. www.gov.uk/government/publications/spring-budget-2023/spring-budget-2023-html
2. www.gov.uk/government/news/initial-100-million-for-expert-taskforce-to-help-uk-build-and-adopt-next-generation-of-safe-ai

CONTEXT

In March 2023, the Government published the Independent Review of the UK's Research, Development and Innovation Organisational Landscape, chaired by Sir Paul Nurse. This major review has a number of key conclusions and recommendations about the way that research and innovation are structured and funded in the UK.

On 15 May 2023, the Foundation for Science and Technology brought together a panel to discuss the review and some of its conclusions. The speakers were: Sir Paul Nurse, Chair, the Research, Development & Innovation Landscape Review; Chi Onwurah MP, Labour Shadow Minister for Science, Research & Innovation; Dr Peter Thompson, Chief Executive of the National Physical Laboratory; and Vivienne Stern, Chief Executive of Universities UK.

A video recording, presentation slides and speaker audio from the event are available on the FST website: **www.foundation.org.uk/Events/2023/The-Nurse-Review-of-the-Research,-Development-Inno**

Setting out a path to the future

Paul Nurse

Sir Paul Nurse OM CH FRS is Director of the Francis Crick Institute, London. A geneticist and cell biologist who works on how the eukaryotic cell cycle is controlled, his major work has been on the cyclin-dependent protein kinases and how they regulate cell reproduction. He is Chancellor of the University of Bristol and has served as President of the Royal Society, Chief Executive of Cancer Research UK and President of Rockefeller University. He shared the 2001 Nobel Prize in Physiology or Medicine.

Research, Development and Innovation (RDI) is crucial for the UK. It is an essential driver of productivity, sustainable economic growth, strategic benefit, and improvements in the quality of our lives and of the environment. It is not just concerned with science but rather with making the UK a successful country.

The review[1] identified significant problems about the UK RDI endeavour, some longstanding and serious. It also proposes ways of fixing those problems rather than announcing new projects. It makes 29 recommendations, which need to be considered together. There are a whole range of actions that flow from this analysis.

I use the phrase 'revolution through evolution' because we should be building on the structures we have, rather than starting again with all the inherent instability that brings.

A key finding is that the UK Government underspends on both the research it performs (i.e. carries out within Departments) and supports (directly funds) when compared with comparator countries. This problem has been obscured by historically poor data collection which has hugely underestimated industrial spend and also the amount that universities themselves invest in research. The review team calculated that the R&D performed by the UK Government is 0.12% which is half of the OECD average of 0.26%.

R&D funded by UK Government amounts to 0.46% of GDP, which puts the UK 27th of the 36 OECD nations, where the average is 0.6%. In fact, the US, Germany, South Korea spend 0.7-1.0%. So, the inescapable conclusion is that the UK needs to invest more in RDI. Further, that investment needs to be embedded in a stable policy environment.

SUMMARY

- There are significant concerns about current UK activity in Research, Development and Innovation (RDI)
- We should build on current structures – 'revolution through evolution'
- UK investment is well below the OECD average
- More focus needs to be placed on full funding costs
- Permeability between different research institutes should be increased.

RDI investment by the Government should also be better delivered. In the past, there has been too much emphasis on just the direct costs of programmes, with insufficient attention to complete 'end to end funding'. The latter includes boring things like administration: the lack of admin support means trivial tasks are given to researchers, distracting them from their main tasks and so wasting money. Sophisticated technical facilities need to be communally available, rather than only found in those labs that attract the highest direct funding. There has to be more of a focus on covering the full funding costs.

The diversity of our research organisations needs to be examined and, indeed, increased. The UK RDI landscape is complex. There are: universities; public sector research establishments (PSREs); research institutes and units; industry; as well as a whole gamut of other components such as academies, museums, translational institutions and the like.

Over the past 30 years, research carried out in

universities and industry has grown while the proportion carried out in PSREs, institutes and other units supported by Government has dramatically shrunk: this is now just one-third of the figure three decades ago. Some 80% of non-business R&D is concentrated in universities in UK, compared with 45-60% in other countries. Our universities are generally very good and highly competitive on the international stage. While they do need continuing support, so too do PSREs, institutes and research units.

PSREs not only carry out discovery research, they provide a national infrastructure for RDI technical services, developing regulatory standards, providing sovereign expertise as well as emergency responses: these are not areas that universities are specialists at delivering. Institutes and research units offer a dedicated laser focus on the research mission and are very attractive to the highest quality researchers. Our best institutes and units are prominent on the world stage.

So there needs to be a review of whether we have the right balance in total spend between different research-performing organisations (RPOs) while at the same time defending the universities. It needs an expanded budget.

Further, there needs to be increased knowledge of – and permeability between – the full range of RPOs in the UK's RDI landscape. Not only is the landscape complex and difficult to navigate, it is highly siloed. Knowledge transfer between the sectors is low. Better understanding and knowledge about those sectors is required to allow effective navigation through that landscape. Finances and capabilities of the different elements must be accurately and regularly reported: without decent data it is not possible to make decent policy. Improved knowledge of the linkages will promote permeability of ideas, technologies and people between industry and academia.

Universities, too, could have a special role in increasing permeability, as happens in the US where some universities provide services to local industry and communities for relevant research. So, in the UK, if you have a company in, say, Middlesbrough and they know there is relevant research happening in Bristol, they should be able to connect to it.

This may be an obvious point, but unnecessary and excessive bureaucracy must be reduced: we need to run the system better. I believe UKRI has a part to play in reducing bureaucracy and defending the Research Councils from restrictive Government and Treasury rules and regulations. The role of UKRI is to defend – and enhance – our research endeavour.

Talent is critical to successful RDI. We need to train talent – and particularly homegrown talent – at all levels, from technicians and lab assistants right through to research professors: they all have much to contribute. There needs to be more permeability across the different RDI sectors – many people in universities are just not aware of PSREs and the opportunities they offer. In addition, early career researchers, technicians, graduate students, postdocs, researchers, etc, need better employment conditions and further training to help them do their jobs more effectively.

We must have effective international RDI arrangements. Central to this is association with Horizon Europe. EU researchers are by far the largest group with which UK researchers interact and collaborate. Over the past 40 years, we have built up a complex arrangement of networks and contacts. Enhanced engagement has almost universal support across the research endeavour. There are three main groupings of science in the world, North America, Asia (particularly based on China) and Europe. We cannot build something separate all by ourselves. However, leadership is needed to get us into that European grouping.

While we are considering the international nature of RDI, it is also obvious that we need to attract and retain international talent. We have to ensure that the UK is an attractive place to do research.

UKRI has a part to play in defending the Research Councils from restrictive Government and Treasury rules and regulations.

A blueprint

The recommendations in the review provide a blueprint for the revolution that I believe we need. But there are some relatively inexpensive actions that can be carried out immediately. Financial sustainability is an issue, for example, through Full Economic Costing, QR and also direct grants. The Government, working with UKRI and others, should establish a planning and implementation group to see how to deliver this in practice.

The review identified significant problems in the running of PSREs. They require mission clarity, permeability, agility and funding. A major problem is quite simply Government restrictions – on how they operate, in their planning and implementation, and the salaries they can pay.

The review also found that a number of recently-established institutes – Rosalind Franklin, Alan Turing, Henry Royce, Tyndall Centre for Climate Change and others – are not working effectively. Primarily, they were not set up with the right budgets, nor the right governance. They should all be overhauled within the next year to identify how to make them work properly.

A significant issue with healthcare RDI is the excessive pressure on clinical researchers due to

We do not yet understand RDI well enough in general and need effective mapping across the country and across all disciplines.

their NHS duties. This is damaging medical research in the UK and needs to be corrected.

We do not yet understand RDI well enough in general and need effective mapping across the country and across all disciplines. Without information, we cannot deliver it.

These are examples of what can be done fairly inexpensively, although there are more expensive challenges ahead as well. But we should remember we are currently investing much less than most of our competitors in the OECD. □

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[1] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1141484/rdi-landscape-

Creating a new future for science and research

Chi Onwurah

Chi Onwurah is MP for Newcastle upon Tyne Central and Shadow Minister for Science, Research & Technology. Prior to her election to Parliament in May 2010, she worked as an engineer in the telecoms sector for over 20 years. From 2004 to 2010 she was Head of Telecoms Technology at Ofcom, focussing on the implications for competition and regulation of the services and technologies associated with Next Generation Networks. She is a Fellow of the Institution of Engineering & Technology (FIET) and the City & Guilds of London Institute (FCGI).

SUMMARY

- We need more private sector investment and a long-term strategy for R&D, underpinned by a mission based industrial strategy
- Constant change militates against investment planning for business
- Labour are considering a long-term 10-year spending cycle for science
- Increasing diversity in STEM sectors must be a priority
- Universities have a vital role in stimulating regional economic growth.

As the review points out, the UK has key strengths and advantages in the fields of Research, Development and Innovation (RDI). Indeed, Britain has a long and proud science heritage – the invention of the steam engine in my constituency for example. We also have a world-leading science base and we rank third in terms of published scientific articles, behind only the US and China.

While UK science is pushing the boundaries of humanity's collective understanding, it also represents a priceless platform for future economic growth and prosperity. As the review concludes, it is only through RDI that 'our country can thrive, driving sustainable economic growth through increased productivity, improving public services and the quality of our lives, protecting the environment and meeting future global and national crises and challenges'. I agree with every word of that.

The review calls for both investment and for strategy. There is work to be done, something the Labour party recognises. We have a vision for Research & Development, for stoking the engine of high-skilled growth, accessing new and diverse talent pools, and catalysing regions that have been left out of science investment.

Due to a lack of investment and a lack of industrial strategy, the UK is not currently converting our rich science base into a high-skill, high-wage, high-productivity economy. While the EU and the US take steps to secure the industries of the future, building sovereign science and technological capabilities, the UK Government has allowed our own science startups to be bought up or to move abroad, due to a lack of UK investment options.

There has been a succession of Conservative Government strategies and plans but little concrete action. There has been an Innovation Strategy, an R&D Roadmap, an Office for Science and Technology Strategy, two National Science and Technology Councils, a Science and Technology Framework – and now a whole new Government Science Department. Since Sir Paul's review was commissioned, there have been three changes of Science Minister!

In the Labour Party, we want to end the pattern of supposedly long-term plans that do not survive a political cycle. The current chopping and changing makes it nearly impossible for science investors and businesses to take decisions about their future direction. Science and business need a long-term vision and a plan to achieve this; one upon which they can rely for more than a few months at a time.

A mission-based approach

We propose not only to have an industrial strategy, but also to put in place a mission-based approach. Our industrial strategy missions are: delivering clean power by 2030; 'caring for the

future' which is about better social care; infrastructure; building a resilient economy; and harnessing data for the public good. These missions will be overseen by an Industrial Strategy Council that will be placed on a statutory footing. That will give confidence to investors in our RDI strategy and its implementation.

The industrial strategy addresses the interface between science and business. Science needs a long-term plan of its own, though. Beyond providing a long-term framework for policy stability and growth, Labour is considering placing core R&D funding for agencies on 10-year spending cycles. Long-term funding envelopes would give the state the ability to be flexible and agile, delivering effective research outcomes and acting as a magnet for global research investment and talent.

We particularly recognise the patchwork, bureaucratic nature of some Government-funded R&D as highlighted in the review. The landscape is very complex, not just for scientists but also for businesses. Access to research funding generally means grappling with the burden of frequent and repetitive reviews, reporting and auditing. These can be extremely time-intensive and in addition place unnecessary bureaucratic and financial demands on public sector R&D funding bodies, instead of allowing them to focus on delivering world-class research and innovation.

So, there is a need for a clear, coordinated and systematic approach to R&D strategy and policy making across Government. It is a challenge the Labour Party has been discussing for some time now: how to ensure the delivery of inter-Departmental science and technology agendas, while developing credible alternatives to the repetitive, multi-layered reporting and auditing currently demanded. We have to find a balance between accountability on the one hand and a culture of confidence and earned trust on the other.

Diversity

We also recognise another finding of the review, which is the existence of a chronic lack of diversity, not only in institutions, but in terms of people and places when it comes to science opportunities and funding. While we are very proud of the Golden Triangle, it receives more public R&D funding than the whole of the rest of England. Further, a full 65% of the UK STEM workforce is both white and male. As Keir Starmer says, we take our strengths from too few places, in terms of geography and demographics.

Labour is exploring how to stimulate a richer diversity of researchers' backgrounds and looking to overcome the inequalities that many face in applying for short-term, incremental grants.

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These barriers include issues around caring and other responsibilities that many from non-traditional backgrounds have.

I was pleased to see the review recognise the key role of universities in building regional economies which are strong and self-sufficient – and not dependent on handouts. That is why we will champion universities and clusters of universities as engines of regional growth. The prospect of universities directing local businesses to relevant research elsewhere is also very attractive.

I am very glad to see the review state firmly that associating to Horizon Europe is vital to maintaining the UK's leading role in globally-important research. For research scientists, both in this country and those thinking of coming here, that lack of association is incredibly detrimental. We must make progress in those negotiations.

The Labour Party believes in this nation's RDI science potential. We see a clear path from science to the jobs that you can, in Joe Biden's phrase, 'raise a family on', the high-skill, high-wage jobs that people are proud of. We need to see these the length and breadth of the country, for our economic prosperity, for our national security and for our social cohesion.

The Nurse review is a great piece of work. Now we need a Government which is serious about science and serious about creating the outcomes that the review seeks. Working in partnership with science researchers, businesses and trades unions, Labour will create a fairer, greener and more sustainable future. □

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Horizon Europe is vital to maintaining the UK's leading role in globally-important research.

There is a need for a clear, coordinated and systematic approach to R&D strategy and policy making across Government.

A wider, whole-system view

Peter Thompson

Dr Peter Thompson FREng FInstP FRSC became Chief Executive Officer of the National Physical Laboratory in 2015. He has led the laboratory's development to align science, innovation and technology to the UK's national challenges, while ensuring that NPL continues to be recognised as one of the world's leading National Metrology Institutes. His previous roles include Deputy Chief Executive of the Defence Science and Technology Laboratory, Strategic Advisor to MOD's Chief Scientific Adviser, and Head of the MoD's Counter Terrorism, Science and Technology Centre.

SUMMARY

- The research landscape is experiencing a great deal of change today
- Leaders of research organisations need to be given freedom to deliver on targets
- Current funding mechanisms do not always allow the most efficient solutions to challenges
- A systems view would encourage more diverse solutions to issues
- The UK needs to promote the benefits of the wider research landscape.

This is a very busy time for research organisations. The Integrated Review sets out how science and technology can deliver strategic advantage for the UK. There have been three independent reviews, including the Nurse review, initiated as a result of the Innovation Strategy, plus the Government's R&D People and Culture Strategy. The National Science and Technology Council was set up, then discontinued and now re-established.

The machinery of Government, too, has recently changed: in addition to the NPL's host Department, the Department for Science, Innovation and Technology (DSIT), there is the Department for Business and Trade which has a significant R&D component, as well as existing Departments with major science budgets.

The Science and Technology Framework references over 50 individual strategies that exist across Government and in connection with its own 10 recommendations. It was published on the same day as the Nurse review. Shortly afterwards, the International Technology Strategy was also published.

So there is much to tackle. Complexity drives cost while efficiency can deliver greater outcomes for the same investment. There are definite opportunities and we should be acting now with all the information we have to aid our decision-making.

Public sector pay

One issue of particular relevance to Public Sector Research Establishments (PSREs) like NPL is the flexibility – or lack of it – on pay. This is not a level playing field. There are fantastic Government-owned organisations within the UK. Nevertheless, it is becoming increasingly difficult to attract the best talent to work within the public sector in the current environment.

More generally, giving leaders the flexibility to decide where to spend their budgets – where we invest, where we spend our money, what infrastructure we need, all the other things that one needs to spend money on – would make a huge difference to our organisations.

Looking at the scope of our work, the Nurse review talks about clarifying the missions and the boundaries. That is all well and good provided they do not work to keep us in a box. Government should be trusting us to lead in areas where discovery-driven research can enable the discoveries that build the future. A great deal of time and investment goes into recruiting leaders for PSREs; they are, after all, public appointments. So let us lead and then hold us to account for the outcomes we deliver.

I am particularly attracted by opportunities to take on new initiatives. The UK Telecoms Lab was set up under DCMS and is now part of DSIT. NPL was asked to take the lead on this initiative. We went through a comprehensive process of due diligence, but if we had taken a very narrow view we could have argued that it was really outside our boundaries. That would have been an inefficient decision and, instead, we now look forward to delivering outcomes for Government through this national facility.

Full economic cost

One of the factors that affects lots of colleagues is the Full Economic Cost issue. This has been an issue for a long time. We need a senior responsible owner to solve this. When the best resources are identified to address a particular mission or national challenge, it is nonsensical if the relevant organisations cannot take part because of the way that the work is funded. It may not be easy to resolve, but it needs someone to take responsibility and to work across Government, with users and policy owners, to find a solution.

When Ministers see some of the achievements we have made, I will sometimes comment that

It is becoming increasingly difficult to attract the best talent to work within the public sector because of lack of flexibility on pay.

WIKIMEDIA COMMONS / DILIFF

Public sector research establishments such as NPL play a leading role in the UK research programmes.

"Yes, that was a 10 year overnight success." The investments that are put in place for the long term allow us to achieve these results. That does not just apply to PSREs, it is valid across the landscape. And that is why we need stable funding programmes, not just for ourselves but also for the investment community that we have to attract to the UK. This will give confidence to that community.

Systems approach

The approach that I favour is a whole system view. In any system, or system of systems, a focus on the interfaces can make major improvements achievable. Addressing the Full Economic Cost, for example, will enable the whole system to work more effectively. Having a level playing field for people will improve efficiency as people will move more easily between the important nodes of the RDI landscape. That will ensure greater knowledge dissemination between the individual components.

For that reason, I welcome the Expert Exchange secondment scheme that DSIT has set up to bring people into Government. The flow of people will help deliver strategic impact for the UK.

At a national level, proposals to the Strategic Priorities Fund for cross-Government challenges were reviewed by the Chief Scientific Adviser community. That opened up new networks and NPL is now delivering a National Timing Centre capability that supports many different sectors and Government Departments.

Internationally, we often refer to the strength of our universities but do we promote the wider system? There is a range of other organisations which could encourage people to bring their R&D to the UK. NPL, for example, is widely-regarded internationally in terms of developing technical standards. It works with the best universities and the best companies to develop those standards so that companies can compete and trade more effectively in the future.

Organisations will often talk about where they are based as a proxy for the impact they have in those locations. That is only one of the ways in which to deliver impact locally. One programme, called Measurement for Business, has been developed with hundreds of small companies across the UK – mainly digitally – helping them develop their technologies and accelerate those towards market.

The outcome that I want is one that can unleash the PSREs so they can deliver excellent impact. There must be a whole-system view focussing on affordability, understanding what is to be achieved, and measuring the impact. That includes considerations of infrastructure, people and partnerships. And finally, as the Nurse review identifies, all of this needs inspirational leadership and change management across the whole system. □

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Universities have a special place in the research landscape

Vivienne Stern

Vivienne Stern MBE has been Chief Executive of Universities UK since September 2022. She was previously the Director of Universities UK International (UUKi) which represents UK universities around the world and works to enable them to flourish internationally. She has over 20 years' experience of working in Higher Education policy and politics at national and international level. Prior to her role in UUKi, Vivienne was Head of Political Affairs at Universities UK, and led the sector's response to several major pieces of legislation relating to universities.

SUMMARY

- The UK needs to take a longer term approach to research, development and innovation
- Universities are international communities located in the UK
- International students contribute significantly to universities' research spend
- UK research must be part of a wider regional effort
- Universities give UK research visibility on the world stage.

There is a consensus emerging today about the need for a longer-term approach to the UK's research and innovation strategy. It is now 15 years since the Sainsbury 10-year science frameworks were introduced. There have been a number of previous attempts to create stability and predictability through long-term approaches to science strategy.

Of course, it is one thing to say we need a long term, stable approach, it is another to define what that will be and how it differs from the range of options now current. The first, and perhaps most obvious, point is that people seek stable and predictable funding. When developing a proposal, it is important to know that there will be some relevant funding stream available to you and the team you are putting together, so that there is a route to achieve your goal. There needs to be some predictability in the system.

There is ongoing discussion about the merits of Horizon Europe and the UK's place within it. One of the views heard consistently about Horizon is that it has been such a powerful platform due to its seven year investment cycle. A programme is published, so everyone knows what will happen and when. That allows proposers to start building their teams, building networks with suppliers. That stability and predictability have been really valuable.

Contrast that with a period we have recently experienced with research funding in the UK. There has been a series of one-year spending reviews. While it can be argued this was no-one's fault given the prevailing economic conditions, one-year reviews tend to mean that large sums of money are spent in a suboptimal way, with people scrambling to put an application in for a concept that is not fully thought through, just because the money has to be spent before year-end.

So if there is a consensus emerging about the desirability of a long-term approach, what does that mean in practical terms? How would it differ from what has been tried before?

Everybody acknowledges that the UK is fortunate in having really outstanding universities. It is vitally important for the UK that they are open to talent.

Everybody acknowledges that the UK is fortunate in having really outstanding universities. Yet these are not British-only universities: in fact they are locations that host international communities. It is vitally important for the UK that they are open to talent and that they remain the kinds of places people want to come to in order to build a research career.

The universities are places where people pass through and go back to other countries. Note, though, that something interesting happens: these institutions are places where people come and start their journey on an academic career. This is where they start building collaborative networks. So, openness to talent seems to me incredibly important.

There has been a stagnation in postgraduate international recruitment and the UK is falling behind its competitors. It needs to be said again and again that these universities are outstanding because they are international and they host talent from all over the world.

Scale

It would be wrong to think that a research system like that of the UK could compete on the same scale of research production as North America and China. The speed of development of the Chinese research system, both in terms of volume and quality, is astonishing. The level of investment there will dwarf anything that any UK Government could match. Only by playing a part in a


IMPERIAL COLLEGE LONDON

Researchers at Imperial College London, the UK's top-rated research university.

regional system can we achieve the scale necessary to compete.

The Nurse review makes the point that large elements of the resources dedicated to research are not accounted for in official statistics. There are large amounts that universities spend on research themselves – rather than being awarded for example. That extra money comes from a range of activities but primarily from the recruitment of international students – it represents a colossal contribution to the research system. It is a substantial cross-subsidy, supporting the funding of domestic students and we are making this case strongly to Government.

While acknowledging that universities are one part of the overall research landscape, they are certainly the most visible. That visibility results in the extra research resources that international students bring, because people come from abroad to study in our universities. There is a reputational benefit from being associated with a UK university and then going somewhere else.

That is one of the reasons why our universities have a special and important place in our research system. One of the reasons why the UK does particularly well in international rankings (for all of their flaws) is precisely because we do conduct a large proportion of our research in them and that is reflected in the rankings.

Spreading that investment runs the risk of diluting the benefit. While rankings may create unhelpful and unhealthy incentives in the system, that does not stop any Minister quoting how many universities we have in the international Top 10 or Top 100. In identifying a long-term strategy, one consideration must be whether, in 20 or 30 years' time, the UK will still have that advantage. Does it matter whether we are in the upper echelons of the rankings? Or will that remain important?

Having spent a lot of time talking to ministries around the world that invest in institutions in the upper reaches of the rankings, I believe we would be foolish to ignore the power that this status conveys. So I think whatever strategy we craft should not ignore the importance of maintaining UK visibility in this area.

Gateways

The review refers to the gateway role that universities can play in signposting expertise right across the system. Now, in the context of innovation, we have an increasing focus on quite small geographical areas. However, in a country like the UK, we should be pushing towards larger scale. So, if you come to a UK university, it should be able to facilitate connections with other institutions, another universities, or another part of the research system.

Then, of course, there is the question of Horizon Europe. The review says that Horizon provides a platform for us to collaborate with 27 other nations. Actually, it is much broader than that, because all the other 'third countries' in the programme can collaborate with us too. That provides a much larger framework within which to pursue research that will benefit the UK. □

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The debate

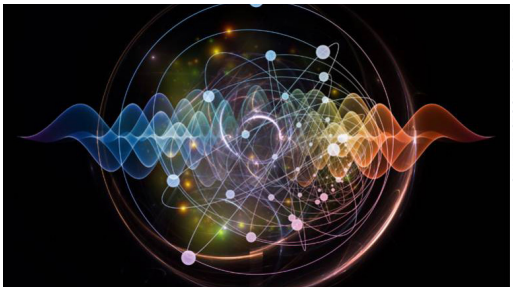
After the formal presentations, the speakers joined a panel and answered questions put to them by the audience. Topics included: discovery and applied science; strategic partnerships; linking to other parts of the research landscape; national challenges; and mapping the landscape.

Discovery science must interact with applied science but there are differences in research approaches between the two. While some areas require a top-down approach, others benefit from a bottom-up approach. These issues are more complex than simply identifying market needs: we must ensure that the entire spectrum of research works together. This does however need to recognise the importance of both commonalities and differences in research approaches.

There are increasing strategic partnerships between PSREs and universities. They benefit PSREs by having valuable wisdom and discussions on reproducibility in scientific research. By sharing knowledge about these efforts more widely, it can cut down the amount of fundamental research that is often repeated by industries, particularly in the life sciences sector.

It is eminently sensible for institutes of all kinds to be linked to universities and larger industrial organisations like Rolls Royce. But there needs to be a more strategic approach. Co-location is desirable in terms of building critical mass. Maintenance of common quality standards is very important.

The UK is capable of bringing a range of different resources together on national challenges. The National Quantum Technology Programme brought together Research Councils, Government organisations and PSREs. It has proved a case study in how this kind of initiative can be made to work.



SHUTTERSTOCK/ AGSANDREW

It is very important to identify and map the web of existing organisations and resources. Currently, this is missing. Without accurate data and information, it is difficult to develop effective policies. It is not a matter of a once-and-for-all benchmarking exercise, regular mapping should be conducted in order to track progress. This would seem to be a very suitable exercise for UKRI to facilitate. The vital importance of accurate data, extensive knowledge, and in-depth understanding to informed policy-making were emphasised by several contributors.

The role of universities in regional growth highlights that most universities aim to contribute to their communities. The importance of long-term funding for stability and scientific advancement was stressed, while it is also necessary for efficient and effective use of scarce resources to guard against funding different groups for the same research aims. □

FURTHER INFORMATION

The Independent Review of the UK's Research, Development and Innovation Organisational Landscape
www.gov.uk/government/publications/research-development-and-innovation-organisational-landscape-an-independent-review

The Integrated Review
www.gov.uk/government/collections/the-integrated-review-2021

FST BLOGS

Nurse Review of RDI landscape 2023 – a medical research charity sector view – by Mehwaesh Islam and Catriona Manville, Association of Medical Research Charities
www.foundation.org.uk/Blog/2023/Nurse-Review-of-RDI-landscape-2023-%E2%80%93-a-medical-res

After five momentous years as Government Chief Scientific Adviser, Sir Patrick Vallance's term of office has come to an end. Shortly after, on 26 April 2023, he joined a special meeting at the Foundation for Science and Technology for a conversation with the Chair of the Foundation, Lord Willetts.

A conversation with Sir Patrick Vallance

Lord Willetts began by asking Sir Patrick about some of the high points – and low ones – during his time as GCSA. One of the key events that stood out, he replied, was the 100 Days Mission which G7 countries and global science leaders launched at their meeting in Cornwall in 2021. Leaders spoke of the unpredictability of future health emergencies and emphasised the need to harness scientific innovation and public-private collaboration to develop an 'armamentarium' of diagnostics, therapeutics and vaccines (DTVs) available within the first 100 days of a future pandemic threat being detected.

At the same time, he recalled that the pandemic was, unsurprisingly, one of the most difficult times. Daily reporting of the number of deaths was chastening while also adding to the pressure across Government to take action to deal with the pandemic and its impacts.

Another issue where he felt that the UK science community made a really positive contribution was on climate issues, particularly at COP26 in Edinburgh, where the UK had delivered the first Science Day at these events. A second Science Day was held a year later at COP27 in Egypt and he hoped it would be accepted as a regular feature of these meetings. The need to communicate and explain the science behind the efforts to mitigate climate change was vital to progress on this major global challenge.

Other developments that he highlighted included the way in which the network of Departmental Chief Scientific Advisers across Government has strengthened and become a real forum for discussing cross-Government issues.

During his time as GCSA, he had been able to establish that, in future, 50% of fast-stream entrants to the civil service would have STEM degrees. It has been one of his contentions throughout his time as GCSA that there is a Science and Technology aspect to most, if not all, issues facing Government. S&T is not a helpful 'add-on' but rather a central factor in policy-making. As such, it is vital that there are sufficient people that can understand the contribution that science can make in all these areas – and that can deliver this information in a timely manner and in a format that ministers can access.

The establishment of the National Science and Technology Council is another important development, once again bringing these disciplines closer to the centre of Government. He believes that it should be as important – and indispensable – to an incoming Prime Minister as the National Security Council already is. At the highest level of Government, the Council would focus on the elements of the 10-Point Plan of 2020, which set out a number of cross-cutting topics covering the whole of Government. Interestingly, while setting up the NSTC, a survey was conducted to see just how many S&T strategies had been created across the different Government Departments. The total was 63!

Security aspects

Lord Willetts pointed to way that national security considerations were coming to the fore in questions about science and technology. For many in the scientific community this was something new and not altogether welcome.

Sir Patrick noted that it was now recognised that scientific and technological innovation might often have national security implications and that this would have to be considered in the future. He referenced the issues around the roll-out of 5G in this country. The 2021 Integrated Review of Security, Defence, Development and Foreign Policy addressed those issues.

The review was concerned about the place of the UK in the world over the coming years. He emphasised that science and technology ran through every chapter.

One of the key ideas in the review was that we had several options in different technology areas, categorised as 'own, collaborate or access'. While some technologies were important for the UK to have end-to-end ownership, in others we might wish to collaborate with others where we would focus on some aspects and not all. In some areas, we might decide that this was not a priority for the

Sir Patrick Vallance KCB Kt FRS FMedSci FRCP HonFREng is the outgoing Government Chief Scientific Adviser (GCSA), National Technology Adviser (NTA) and Head of the Government Science and Engineering (GSE) profession. Prior to this, he was a clinical academic at UCL and joined GlaxoSmithKline in 2006, where he was President, R&D, from 2012 until 2017. During his period as head of R&D, over 14 new medicines were approved for use worldwide, for diseases ranging from cancer to asthma and HIV. His own research was in the area of diseases of blood vessels and endothelial biology.

Inter-disciplinary issues such as climate change require systems thinking. Agencies such as the Advanced Research and Invention Agency (ARIA) have much greater freedom to tackle issues that do not fit into existing structures.

SHUTTERSTOCK/ METAMORWORKS

UK and we would access them from other countries. He suggested we do not want to be only half-good at lots of things: we need to focus on those areas where we can lead. Lord Willetts suggested these decisions might be made on security grounds but Sir Patrick believed that the review's options were more about economic choices based on technological excellence – although clearly in some areas security would be more of a consideration than in others.

The conversation moved on to the topic of how the UK encourages research and innovation. Sir Patrick believes that the creation of UK Research and Innovation (UKRI) has been a positive step, bringing the different research agencies – and in the case of Innovate UK, the development funding agency – together to coordinate budgets and priorities. There is an increasing focus on issues that are inter-disciplinary, where systems thinking is required to tackle the big challenges – climate is an obvious example of this.

Yet there are other possibilities too, the Advanced Research and Invention Agency (ARIA) being a case in point. This will have much greater freedom to tackle topics that do not fit into the existing structures and is based on the US ARPA model. It has attracted a great deal of interest. A key consideration is that it should not be constrained by a great deal of bureaucracy.

In terms of accountability, Lord Willetts asked about the funding model for research, and particularly the Haldane Principle where Government does not determine which projects are funded. Sir Patrick remarked that continued funding for curiosity-driven research is essential. He made the point that in business the easiest part of the budget to cut back on is the research budget. While it may provide immediate savings it is fatal for business success in the longer term. A business that does not invest in R&D defines itself as a low-profit, commodity-driven operation.

He said that he had made clear to civil service Departments that the same methodology applied in Government too. He was pleased to see that investment in R&D by Departments has been increasing in recent years. He also noted that the Government's Science Capability Review, published in 2019, which resulted in 15 recommendations designed to enhance the application of scientific solutions in policy-making across Whitehall, was produced jointly by the Government Office for Science and the Treasury.

Horizon Europe

Regarding academic research, he was asked for his view on whether the UK should be part of Horizon Europe or if we should look elsewhere to build links. He stated quite simply that association with Horizon was a 'no-brainer'. He said that failure to take part would disadvantage both the UK and Europe. He highlighted two specific benefits beyond the simple opportunity to collaborate with researchers across many other countries.

First, Horizon has a different set of review processes and reviewers who come up with different answers than we get domestically: that is a benefit. Second is the fact that the programme is at a scale that the UK cannot replicate on it own. With other countries like China expanding their research provision, we need to be part of a wider grouping ourselves. Horizon is important for us. There will be a negotiation around the new

terms, but he hoped that this could be dealt with as soon as possible and that we could start taking our part in this programme.

Sir Patrick was asked about the lack of scientific expertise in Government and Parliament – and particularly the House of Commons. He noted that the House of Lords, as a revising chamber, relied on peers with specialist knowledge and that here science was well represented. But science and politics take different approaches. A scientist looks for evidence that may throw new light on a subject and which may lead to a significant change of direction. Uncertainty is a core element of scientific research – and progress. When a Government changes course, on the other hand, it is often accused of a U-turn in the press.

Popular perceptions of science can be unhelpful too. Many non-scientists believe that scientific truth is black or white, with no room for uncertainty. So when, as in the pandemic, scientific knowledge was changing rapidly with a range of views on what was happening and what should be done, this was confusing for the public. However, the Covid crisis did lead to a big upsurge of interest in science in general, an interest that has been maintained since.

He was asked by a senior civil servant in the audience how Government could attract more talented scientists into the civil service. Sir Patrick noted that the public sector cannot compete on salary, although it needs to address the level of disparity if it wants to attract the best from industry and academia. Ultimately, though, it must offer something else.

For him personally, when he was considering the role, it was the sense of purpose, of making a difference, that was pivotal. That sense of being able to do something important is where Government wins out. We need to major on purpose, he said. Many young people are very concerned about the future of society and the world and this offers an opportunity to make a real difference.

He also referred to the way in other countries, such as the US, it is easier to move between industry, academia and Government. That needs to happen here too. And transitions should not be one-way and permanent. Again, in the US, it is not uncommon for people to move from, say, industry to Government and then, a few years later, to return to industry.

Among the challenges facing society, two that were raised were: the ability to achieve net zero by 2050; and the impact of AI on the future of work. Sir Patrick argued that the key issue on the first of these is the challenge of developing technologies at scale in time to meet the target. The UK in particular – although it is not just a UK problem – has not been good at providing the support necessary to take discovery-based science through to industrial scale deployment. We have not traditionally been able to attract investment from large institutions like pension funds. He referred to the example of Canada, where all the teaching pension providers had been brought together into a single organisation which now makes significant investments in science and technology.

In regard to climate, there are a range of issues that need to be addressed and solved. Changing behaviours is going to be a major challenge in the coming years. But in terms of technology, scaling up is vital. And he added that we have not much time left to do this. We have to use the technologies we already have if we are to reach our target in a little over two decades.

With so many interlinked factors to consider, there must be a major systems-based programme set in train. And specifically, this will need to focus on engineering and particularly systems engineering. A whole new generation of engineers will be needed to deliver the necessary changes in time.

The future of work

Among the new technologies coming forward are those associated with Artificial Intelligence. These will have a major disruptive impact on the workplace. He likened it to the scale of change that happened in the industrial revolution. That will mean profound changes for society and the Department for Education will need to become far more adept at helping people to re-skill for new roles as these become available.

In closing remarks, Sir Patrick noted four considerations that scientific advisers should always consider. First, is the evidence base adequate? If not, what should be done about it? The second is: has the evidence been understood in the context of associated uncertainties? He argued that one of the key roles of the science adviser is to make sure the uncertainty has been properly articulated. The third is to consider if the scientific advice has been framed in a way that is relevant to policy. While that may sound trivial, it can be the case that the scientist wants to convey some information that they think is important because it was discovered yesterday. It may not be relevant to the policy under consideration, though, or framed in a way that policy makers can use. Then the fourth, and in his view really crucial, factor is how can science be used to monitor and assess the effects of adopted policies: have they actually worked or not? □

www.foundation.org.uk/Events/2023/In-conversation-with-Sir-Patrick-Vallance

DOI: 10.53289/EXAI2486

Many non-scientists believe that scientific truth is black or white, so when, as in the pandemic, scientific knowledge was changing rapidly, this was confusing for the public.

CONTEXT

The issue of skills has been discussed regularly over the years at the Foundation for Science and Technology, and with rapidly changing technological and work environments it remains a critical issue. In this event, we focussed on preparing the next generation for a technological life and examined the roles of schools and FE colleges in contributing to post-16 technical education. The meeting discussed topics such as University Technical Colleges, T-Levels and industry placements, as well as the wider profile of Further Education.

The meeting was held at the Royal Society on 22 February 2023, bringing together: Professor Bill Lucas, Director of the Centre for Real World Learning at the University of Winchester; Nancy Buckley, Group Director, Business Development at Activate Learning; Sharmen Ibrahim, Group Director, Digital Education at Activate Learning; Ella Podmore MBE, Senior Materials Engineer at McLaren Automotive Ltd; and Phil Smith CBE, Chairman of IQE, Chair of Digital Skills Partnership and former Chair and CEO of Cisco UK.

A video recording, presentation slides and speaker audio from the event are available on the FST website: **www.foundation.org.uk/Events/2023/How-can-education-help-tackle-the-technical-skills**

Practical learning for life

Bill Lucas

Professor Bill Lucas is Director of the Centre for Real-World Learning at the University of Winchester. His research focusses on understanding those dispositions for learning which help people succeed and flourish in life. He is the co-founder of Rethinking Assessment. With Dr Janet Hanson, Bill has developed a way of thinking about engineering as a series of engineering habits of mind (EHoM), one of the educational ideas of the last decade according to IMechE.

SUMMARY

- Good learning involves head, heart and hands
- Learning has become overly focussed on knowledge at the expense of other aspects
- Real-world problems offer excellent opportunities for effective learning
- Key skills and dispositions need to be absorbed from the earliest days in school
- A Digital Learner Profile would provide a lifelong record of a wide range of learning experiences.

Schools and colleges can prepare young people for a technological life, while at the same time tackling the technical skills gap, by rethinking the relationship between knowledge skills (both technical and social) and habits and dispositions for learning. In addition, there is the value and power of practical learning. It means engaging head, heart and hands. Good learning is a combination of those three elements. In school, though, we become fixated on the head.

I have been working with the Royal Academy of Engineering for more than a decade to understand better how engineers think and act. That has involved a move away from thinking of them as 'Subject X' experts (whether mathematics, physics or other disciplines) and to think instead about the way they see the world.

The result of that research was a focus on a series of six 'engineering habits of mind': systems thinking, adapting, problem finding, creative problem solving, visualising, and all the while improving. Then there are wider, more generic learning habits of mind of the kind that make us human: curiosity, creativity, reflection, resilience, persistence, etc.

With the Royal Society, we have been looking at the demise of practical science, which has been reflected in the demise of practical educational experience across the spectrum. We live in a technological age where we apparently do not have to experience things, we can just google them. If we go running, we can compare ourselves with others, we can think about where we are going and why we are doing this. Rather than remembering what that plant is, we can use our phone with a smart app. We do not use maps anymore, we have a satnav.

I asked ChatGPT for the answer to the question: 'How can schools and colleges prepare young people for a technological life and help tackle the technical skills gap?' The reply was: 'There are several ways schools and colleges can prepare young people for a technological life and help tackle the technical skills gap' followed by a number of relatively straightforward suggestions. What ChatGPT does not have is the unique capability of the human mind to think things which have not been thought: it cannot sample such ideas and present them. Perhaps it takes a novelist to remind us of that.

Here lies the difficulty in the current obsession with knowledge. It is not the only capability young people need to acquire while they are in formal education. They need skills and competencies as well as habits and dispositions. Working out how to do something means applying the


ASTUDIO

School21 in East London embodies the educational approach of "head, heart and hands".

knowledge in a context. When that is done regularly, it becomes a competence. With practice it becomes a default setting. If you like, habits are one stage further, we are disposed to do something. The false division between mind and body has serious consequences.

For engineers, medics, and interestingly in Higher Education, the way that people are often trained is through problem-based learning. It does not start from the curriculum, but from the challenge of a real-world problem.

Rebalancing

What needs to be done? First, we need consciously to rebalance head, heart and hands. There are already schools that are doing this very effectively.

Second, we must embed these habits from the start of the education journey. How do children learn to be resourceful when writing a poem? How can they learn resilience when dealing with a tricky scientific experiment? How are ethics built into learning? How can curiosity be supported when the examination system will often only reward one right answer? These engineering Habits of Mind, developed in conversations with engineers, are the kinds of behaviours that will be needed by the next generation of young engineers and scientists.

With the founder of School21 in East London, Peter Hyman, we have created a new movement which argues that all school leavers should leave formal education with a Digital Learner Profile. This would, of course, include the more formal major literacies and subjects studied but also other courses, especially those which are interdisciplinary and perhaps also those that have taken place in the community, or as part of work experience.

It would focus what are termed the 'three Cs', really important dispositions around creative thinking, collaboration, and communication. Then, it will also focus on matters that all learners throughout their lifetime have to reflect on: How did I do? How am I doing now? How am I doing as a learner? There will also be an opportunity to include testimonials, photographs and other evidence of one's work.

We were delighted that the final report of the recent Times Education Commission recommended this approach. The qualification they proposed involves a broad balance between practical, applied and academic aspects of the curriculum which all young people would pursue through their school lives.

Good learning involves head, heart and hands working in harmony. Teachers should use carefully chosen strategies that encourage learners to experience and navigate real world challenges, acquire and apply their knowledge and through a range of settings that explicitly develop skills, skills and dispositions for lifelong learning. ❐

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The way that people are often trained does not start from the curriculum, but from the challenge of a real-world problem.

The Further Education perspective

Nancy Buckley

Nancy Buckley is Group Director of Business Development at Activate Learning, one of the largest education groups in the UK. Activate Learning runs seven colleges in the Oxfordshire, Berkshire, Surrey region. It also sponsors ALET, a multi-academy trust of schools including UTC Reading and is the lead partner for UTC Oxfordshire in Didcot. It offers 20,000 places for learners in vocational and academic education (as well as adult education courses). It has a focus on apprenticeships (including upskilling existing workforces), lifelong learning and T-Level qualifications (the technical equivalent of A Levels). Lifelong learning includes apprenticeships, Access to HE and funded courses for older people.

Employers are really interested in a student who has resilience, that is professional, turns up on time, is appropriately dressed and can get themselves to work.

SUMMARY

- T levels are a recent development in Further Education
- The key differentiator for these new qualifications is the industry placement
- The courses have been designed with the collaboration of industry, education and Government
- Education is about developing the whole person – knowledge, emotions and motivation
- Industry placements offer experience of the real world of work.

I am not a teacher but I entered the world of Further Education to bring employability skills and a business profile into the college. I am still doing that today, bringing employers into the college to meet students and talk to them about all the different careers that are available to them. We have seven colleges in Activate Learning. We are an apprenticeship training provider, we have an online platform as well as some international operations.

Following primary and secondary school, it becomes the FE world's job to look after many 16-plus learners. We usually only have them with us for two or three years. It is sometimes only at the age of 16 that the students get to practise and hone the habits and skills that they will need in the vocation they have chosen to study.

Pathways

There are several pathways for a student in post-16 education. They can continue with A levels, usually in sixth form or at a college. They can study various vocational programmes, undertake apprenticeships or they can now opt for a T level.

This is a technical qualification equivalent to three A levels, but in a particular vocational subject area such as engineering or digital technologies. Essentially, the T level encompasses a core of technical qualification time at college, which can be anything from 20-50%. For example, with a hospitality T level, there will be a generic cookery skills unit in year one, with a specialism in baking or butchery in year two. That all takes place in the college.

The real differentiator is the industry placement, which can be anything between 315-420 hours over the length of that programme – around 45 days on a job placement with an employer.

T levels have been developed by employers, universities and colleges in partnership with the Government to provide the skills that employers need. The first T levels have been developed in digital technologies, in construction, health, education and childcare. Activate Learning has around 300 students on these courses, with the majority in the health sector.

We find placements for them with our local NHS hospitals and services. The course also includes additional elements including Maths and English if they have not already achieved their Level Four qualifications. Even if they have, we keep giving them Maths and English challenges, because that is still so important.

We believe T levels are an exciting new qualification and they certainly seem to be gaining recognition and popularity – and that is true for both parents, learners and employers.

Our philosophy aims to bring together the brain, the emotions and the motivation. So we encourage our students to practise repeatedly, to read and research and develop their knowledge. We work with them on the motivational aspects and on their whole emotional psyche to give them the confidence to go out and be successful.

Underpinning our approach is the goal of developing the whole person. When I visit employers and talk to them about placements, they are not so interested in the technical qualification that a student might come out of college with – they can provide that training themselves. What they are really interested in is a student that has some resilience, somebody that is professional, turns up on time, is dressed appropriately and can get themselves to work and keeps returning. Not all 16-year olds have those skills but they need to develop them.

Industry placements are the key to the T level. This is where students get a taste of the real world. The 16-year olds that are in college now

CREDIT

have probably had two years at home during the pandemic where they did not even get to school to socialise and meet with people. For some of them, walking into an office or an engineering workshop would be the first time they have been in a professional space.

High-quality placements

We have 300 students studying T levels in health, engineering, digital sciences and business. One whole class of students goes to John Lewis/Waitrose in Bracknell, 40 students go to Oxford University Hospital and six are at BMW. We have to ensure that the placements are of high quality, and that they are of benefit both to the students and the employers.

It is not a simple task finding employers that will take on a student. It is, after all, no small ask for a busy employer to have a 16-year old there every week, finding meaningful tasks for them to do. We also have to ask the employer to assess the students' performance, that they are doing the right thing in the workplace while contributing to their learning as well. So ensuring the consistency of industry placements is really important.

We have to check that the students are arriving on time. Those attendance issues are relatively easy when they are coming into college, but we also have to check their arrival at 30 or 40 different placements. We have to help educate our employers about looking after younger people than they ordinarily have within their workplace. So, teachers need to help educate both students and employers.

Colleges have to be innovative in using alternative delivery methods to get across our teaching as well. Upon completion of the T level, just like A levels, students can go on to university if they wish, or undertake further technical training qualifications such as a higher level apprenticeships. Others choose to go straight into employment. Some of the students that have been out on placement are getting interviews with the employers about taking on a full-time role with them once they finish their education, which is fantastic to see.

We see the T level as a really important option in Further Education. There are still some challenges to be addressed. But we are working very closely with the Department of Education and other partners to make sure the lessons being learned are feeding back into the development of these qualifications. ❑

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Industry placements are the key to the T level and are where students get a taste of the real world. After two years at home during the pandemic it is often the first time they have been in a professional space.

Some of the students that have been out on placement are getting interviews with the employers about taking on a full-time role.

Living in a digital world

Sharmen Ibrahim

Sharmen Ibrahim is Group Director of Digital Education at Activate Learning Group. She has led digital education provision for the group since 2017 and has been working closely with curriculum colleagues to ensure the implementation of a digital strategy across the group. This includes the contextualisation of digital competencies across different curriculum areas.

With a background in Higher Education, my introduction to the concept of Further Education and vocational training came when I relocated to the United Kingdom in 2015. In my home country, the educational path typically involved finishing school and proceeding directly to university or seeking employment. However, upon completing my engineering degree, I realised that while I had acquired a significant amount of knowledge, I lacked certain essential skills required to fully utilise that knowledge in a professional setting.

Although I possessed the necessary technical expertise to contribute to meetings and discussions, I struggled when it came to creating engaging presentations for my audience. Through my experience with vocational learning, I recognised that learners entering the job market require more than just technical knowledge. Employers seek qualities such as resilience, social skills, and motivation too.

Neuroscience

At Activate Learning, we have developed a comprehensive digital strategy that encompasses various key drivers. Technology is an evident aspect, but our learning philosophy extends beyond that. We incorporate neuroscience principles through the utilisation of digital applications and we place a strong emphasis on leveraging digital tools for student wellbeing. Our aim is to equip our students with the skills necessary to become global citizens who can effectively communicate digitally and collaborate with others. Furthermore, recognising the growing importance of sustainability to younger generations, we integrate sustainability education into our digital strategy as well.

The development of the digital skills strategy really started in 2017 and it has gone through a number of iterations. First, we tried to deliver it as a standalone subject called digital skills, and then we included it in our enrichment programme. Now, it is an integral part of the curriculum.

We launched our digital competencies framework in March 2022. We introduced it to staff in April and had everybody trained on the '6 Cs' as we call them: creation, collaboration, connection, curation, communication and critical thinking. Our goal then was to establish a baseline for our staff and students so that they all knew where they were and how they could improve those digital competencies.

SUMMARY

- Digital skills and tools apply to all areas of our modern world
- Young people need more than just technical knowledge as they enter the world of work
- Students need to understand why these skills are relevant to their lives
- Staff need to be able to communicate the importance of these skills to their students
- Digital skills need to be adapted to individuals – there is no uniform solution for everyone.

We have built a digital competencies diagnostic assessment tool that possesses unique capabilities. What sets this diagnostic apart is its ability to guide users along different pathways based on their individual levels and aptitudes. Recognising that a one-size-fits-all approach is ineffective, our tool creates personalised profiles for each student and staff member.

At the start of the academic year, we start with Connect to College Week, or 'week zero'. During this time, no formal teaching takes place. Instead, we introduce students to various elements of college life. This includes familiarising them with their chosen vocational areas as well as introducing the concept of the six competencies. We also touch upon important topics such as online safety and safeguarding, which are crucial considerations for students of 16 years of age.

We then start contextualising digital competencies. To give an example, I went into a construction classroom and I asked a student there: "What do you want to learn?" "I just want to learn how to lay bricks," was the reply. I then said, "And what do you want to do when you finish?" "Oh, I'll have my own business."

So I then explained that to set up a business, they would need digital skills. They would need digital skills to manage employees, interact with customers, complete accounts. The penny dropped, they realised they needed this. But sometimes at 16, it is really hard to get that point. So we have to equip our staff with the skills to demonstrate to students why they need these digital competencies.

In November 2022, we went through an inspection by Ofsted. One of the inspectors

Learners entering the job market require more than just technical knowledge. Employers seek qualities such as resilience, social skills, and motivation too.

expressed particular interest in our digital strategy, seeking evidence of its integration, how students were assessed against it, and the demonstrable impact it had. From the perspective of Ofsted, we had a novel aspect.

Our promotion of digital literacy extends across diverse areas of study. Our digital strategy permeates many other disciplines. We teach students how to visualise their ideas and products in two and three dimensions, employing technologies like 3D printing facilities available at our campuses. This practical approach allows them to design items and then witness their creations come to life.

The product we have developed is versatile and encompasses a wide range of features. It offers students a diagnostic assessment that guides them into personalised pathways. We have also devised pathways for staff, taking a pedagogical approach. The structure incorporates a matrix consisting of six competencies, each comprising four attainment levels.

This undertaking has required a significant amount of effort, with approximately 1500 activity cards tailored to different levels and subject areas. We provide digital clubs and cater to the specific needs of our high-need learners through differentiated approaches. Recently, we introduced programmable LEGO sets, allowing our high-need learners to engage with digital concepts effectively.

With this system, each teacher gets a toolkit; they can apply the contextualised digital inputs in their own subject areas. Students like it because it makes sense to them. For example, a student who is studying access to nursing can use it to understand the secure management of patient records. Ultimately, we are able to offer our students and staff a comprehensive tool that helps them make sense of our digital world and show how it is meaningful for them. □

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Recently, we introduced programmable LEGO sets, allowing our high-need learners to engage with digital concepts effectively.

Broadening our search for tomorrow's engineers

Ella Podmore

Ella Podmore MBE is a senior materials engineer working for McLaren Automotive. She is responsible for all materials-related investigations across all projects of the business, specialising in surface treatments and microscopic metallic analysis. During her time at McLaren, she has won IET's Young Woman Engineer of the Year 2020, been named in Surrey's Top 40 Under 40 in 2022 and more recently received an MBE for contributions to engineering, innovation and diversity.

SUMMARY

- An industrial placement on my degree course was a pivotal moment in my education
- Being able to see oneself in a role or industry is an invaluable skill in building a career path
- There are many avenues into a science or engineering career beyond just a degree
- Changing the perception of parents about career options is really important
- Increased diversity will be essential for industrial success in tomorrow's world.

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.

That placement gave me a purpose. I picked up so many things in terms of professional interaction, but was also able to understand what made a company tick. It gave me a topic to focus my thesis on, which was later published and allowed me to get the job offer and role at McLaren. Understanding what is going on in a business is only really possible by immersing yourself in that particular type of experience. That is why I am such an advocate for this type of opportunity.

McLaren offered me the position of materials engineer. They did not have a materials division at that time. The engineering focus was mainly mechanical and automotive. Today, it is important that industry looks further than just the traditional routes and talent pools. Embracing the worlds of materials scientists, coders and software programmers is going to be essential for the future of UK manufacturing, especially if we want to compete with the tech giants and startups for the best new talent.

Yet it was not the studies or even the exam results that have been most impactful on my journey. I would have to say that it was the softer skills – perhaps 'life skills' is a better term – that I have acquired. These are the things that I will carry with me throughout my career.

As a STEM Ambassador, I frequently visit

MCCLAREN AUTOMOTIVE

McClaren offers an extensive technical training programme as well as mentoring support to its employees.

schools and colleges, talking to students with the aim of convincing some of them to consider science, technology, engineering or maths as an option. My life skills often come into play there as well. What I have taken away from going to schools and colleges are two main insights. The first is the importance of visualisation. This has been a really important element in my journey too. It is so important for students to pick up on. How does a particular career choice relate to their everyday lives? Can they picture themselves getting into a particular job or a particular industry?

We must shed the stereotype that only those in the top set for maths can become engineers, there are so many more routes into a rewarding career than that. I see visualisation, the ability to see oneself in a particular role or industry, as a key asset in pursuing a career path.

Parents

The second insight relates to parents – and specifically the education of parents. I do a great deal of work directly with students, but also with teachers and professors. I see how influential they are – I know how important they have been to my particular career pathway – but the role of parents is key. We must change the perceptions of parents and their aspirations for their children's future. We need to move them on from thinking that only university degrees can get their children into engineering or scientific companies, or that to get onto that pathway they must achieve straight As in school.

In order to move forward as an industry and a country, we need to broaden and diversify our workforce. We also need to diversify our workforce in order to get a diversification of product. So as we look forward to what the UK manufacturing scene can be in the future, and I obviously talk on behalf of the automotive industry, I am excited to talk about ways to give young people that sense of purpose, resilience, creative thinking, outside of the classroom – in fact, the life skills that have been so influential to my career.

McLaren works with a wide range of groups and organisations, seeking out the skills we are looking for, in particular software and coding which will be so important for the automotive industry. Yet there is always more to do. Being close to London, we are already competing with tech giants and startups for new employees.

Interestingly, those companies are often already considering life skills in their application processes. The automotive industry is still focusing on formal qualifications: that degree and those particular grades. Yet, although my application dealt with educational background, my interview was concerned with questions like: How would you handle conflict? If you were managing a sports team and a star player was off sick, how would you maintain team morale? So, while the tech industries are picking up on these personality traits in their applications procedures, we need to change ours to match.

Diversity and diversification

Diversification is vital for the automotive industry in other areas as well, such as the transition to net zero, decarbonising society and moving to autonomous technology. Mechanical engineers will not provide the diversity we will need to deliver all the new products and technologies in a rapidly changing world. We will have to target skill sets rather than just educational grades.

As an industry, we can certainly address any technical skills gaps. The challenge is to change the narrative when talking with students and children. The key message to our aspiring scientists and technologists is that they do not have to be the most talented person in their maths set in order to get into engineering or science.

It is also important to recognise the contributions that individuals can make, whether it be by signing up employees (or yourselves) as STEM ambassadors if you are working for a technology firm, or if you are part of the education system, by reaching out to local STEM ambassadors. That kind of engagement can make such an impact on the potential scientists and engineers of tomorrow. □

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Digital skills will be needed everywhere

Phil Smith

SUMMARY

- Virtually all future work roles will involve digital technologies
- Eight million people in this country lack the digital skills needed for the workplace
- UK productivity continues to lag behind that of our major competitors
- All young people need core skills in collaboration, communication, creativity and critical thinking
- Digital skills need to be made contextually relevant to people.

The Digital Skills Council has been set up to address some of the gaps in the digital skills portfolio. We are living in a world now where technology pervades everything, not just the areas we have known about for years like shopping and travel, now also areas like health. The challenges of net zero and climate change mean these technologies will become much more far-reaching. With the advent of more advanced digital technologies like AI and quantum we will see a much greater impact.

People will be taking on roles and working in environments that are very different from those that we have used to date. National Grid has been talking about the need to recruit 400,000 people up to 2050, many in very technical roles, like smart grid, Internet of Things, and so on. The Faraday Institute, which is the battery institute, estimates that of the 182,000 existing vehicle technicians, only 20,000 or so have electric vehicle expertise.

Higher-value jobs

No matter what the role is, in future it will involve digital technology. The good news is that many jobs will be higher value and higher skilled. So, as an economy that needs to succeed in an increasingly complex world, where we also want to create higher-value jobs, it is good news that we are preparing people for this transition.

However, there are significant challenges and a long way to go. There are hundreds of thousands of job vacancies quoting the need for digital skills in particular. Employers have to find a way of bringing these skills into the system in order to fill the roles that are already available, as well as those we need to create for the next generation.

One of the fundamental challenges concerns the level of digital skills across the nation. Lloyds Bank has been tracking the 'Essential Digital Skills Framework' for the past six years. It turns out we have more than eight million people in this country who do not have the essential digital skills needed for work. That is shocking.

If we look at some of the opportunities opening up in the advanced industries, we need to be building a pipeline of people to take advantage of them, not just find the experts at the top levels. The Digital Skills Council is looking to see how we build the bottom of the triangle as well as the middle and top.

There are two key gaps that have been identified in that Essential Digital Skills Framework. The first relates to safety. Do people have the confidence to go online? Can they navigate that environment safely? Do they need help?

Digital skills

There are, however, some encouraging statistics here. In 2020, only 37% of people in the 18-24 range had the essential digital skills, but by 2021 that number had risen to 70%. That has probably been stimulated by the necessity to use digital technology during COVID – but it is a very encouraging trend.

The second gap relates to our competitiveness and productivity as a nation. The UK still lags significantly behind our competitive nations, some 17% behind the G7 in terms of productivity. The two items that can most affect that figure are, on the one hand, leadership and management, and on the other, technology adoption.

Many businesses, particularly small enterprises, do not have the confidence to harness technologies because they do not have the skills that

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We have more than eight million people in the UK who do not have the essential digital skills needed for work. That is shocking.

DENISE APPLEWHITE/ PRINCETON UNIVERSITY

Gender imbalance: Only 19% of those in technical jobs today are women.

underpin them. We are behind many of our European counterparts in this regard.

Partly, this is due to the speed at which the technical learning environment is moving. In fact, it is not providing what we need. Only 19% of those in technical jobs today are women. There is something quite fundamental about the system that is not correctly addressing our needs.

Next steps

The discussion about what to do about this is often held back by issues about the subjects people study, particularly the need for more participation in STEM. While this is extremely important, it is not the whole story. Take for example computing, which has undergone great change over recent times. The curriculum was revised in 2014 and a computing science GCSE was put in place. Unfortunately, many people were turned off the subject and did not continue with it. There is a real problem with the way it is perceived. The focus on physics, maths and so on, does not reflect the changing dynamics of society. Everybody should be able to access a level of baseline capability: this would be very attractive to people within a business environment.

People often ask: what skills do businesses need? As a business person, I am not sure there is a simple list. Even if that were possible, these needs may change in the future. There is much discussion about apprenticeships for roles in cyber intrusion analysis. In my business, I definitely need some of those today. Will I need them in 20-30 years' time? I am not sure. Many current roles may be made redundant by AI and other capabilities.

However, there are certain fundamental characteristics that need to be included on courses for young people. Almost all education should be framed around the core qualities of collaboration, communication, creativity and critical thinking. In the digital arena, we have also been looking at how young people can understand what a career in this area might entail and whether it is something they might want.

An OECD definition of digital skills is that this is 'problem-solving in a technology-rich environment'. That is a useful way of characterising it. For a plumber, that means sending invoices, communicating with customers, ordering supplies, and so on. A nurse needs these skills in order to spend more time in front of patients and less filling in forms. Digital skills have to be made contextually relevant. I hope to see much more of that kind of thinking in the engagement of business in apprenticeships. This is of course in addition to the subject-specific qualifications that enable students to progress into business environment. Ultimately, we need to focus more on the skills which bring the right skills into business, rather than focussing purely on the job specification. □

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The debate

After the formal presentations, the speakers formed a panel and answered questions posed by the audience, on topics such as: practical work; scaling-up best practice; online delivery; direct interaction; and sector fragmentation.

A recent Ofsted report highlighted the worrying lack of quality and quantity of practical work in schools. That decline started before the pandemic, but nevertheless it represents a major risk in the education system, feeding into industry and the workplace.

We have an underfunded school system that does not have the teachers needed to deliver the quality of education needed by employers. However, there are many examples of excellent practice. We have to become much better at scaling-up these instances of great practice, identifying those people who are doing fantastic work and then curating and understanding it all. But it must be noted that best practice may not necessarily translate immediately from one context to another.

The shortage of teachers does not just concern Maths and English, there are other very difficult areas to recruit for as well, such as digital. Partly, it is a matter of location. If someone is based in Oxford, they will not want to travel to Guildford every day: indeed, the travel time becomes prohibitive. However, if they can deliver this specialist knowledge and its practical application online, that adds value to the learning experience for the students. Contextualising digital, explaining its relevance to careers and practical skills, actually ticks two boxes: equipping the learner with an understanding of digital but also the right skills for their industry.

PIXABAY/14995841

Another way of tackling the shortage of teachers, and McLaren have been doing this recently, is liaising direct with local enterprises and other organisations, including educational establishments, and talking to them about difficult-to-fill posts, such as software engineers and coding engineers. That direct communication has proved very helpful and enabled the engineering firm to fill job roles locally.

One of the issues facing the skills agenda is huge fragmentation. There is a lot of money being spent on skills by companies, by a range of organisations, by Government, and so on. But it is not all working together particularly well. For example, a small business trying to recruit may find it a very confusing environment out there. Many of the big tech companies such as Google, Microsoft, Amazon, Cisco, etc, have fantastic skills programmes but in the past they have not interacted at all on them. With Government and industry support, it may be possible to change this. □

FST PODCASTS

Technical Education & Technical Skills – with Dr Hilary Leevers of Engineering UK
www.foundation.org.uk/Podcasts/2023/Hilary-Leevers-Technical-Education-and-Technical-S

Technical Education and the LSBU Group – with Professor David Phoenix, Vice-Chancellor of London South Bank University and CEO of the LSBU Group
www.foundation.org.uk/Podcasts/2023/David-Phoenix-LSBU-Group

FST BLOGS

University Technical Colleges – Educating today's young people for tomorrow's careers - Simon Connell, Chief Executive of Baker Dearing Educational Trust
www.foundation.org.uk/Blog/2023/University-Technical-Colleges-%E2%80%93-Educating-today-s

CONTEXT

In 2022, the Government commissioned the Rt Hon Chris Skidmore MP to lead a review on the UK's progress to deliver net zero greenhouse gas emissions by 2050. The report of this review – entitled Mission Zero – was published in January 2023. The review concluded that net zero is a massive opportunity for economic growth and the UK is well placed to realise that opportunity, but swift action is needed.

The Foundation for Science and Technology organised a webinar on 21 March 2023 to discuss the recommendations of the Mission Zero report, along with the latest report by the IPCC, and the actions needed to get to net zero in the UK by 2050. The speakers were: The Rt Hon Chris Skidmore MP, Chair of the Net Zero Review; Lord Adair Turner, Chairman, Energy Transitions Commission; and Professor Emily Shuckburgh OBE, Director, Cambridge Zero, University of Cambridge.

A video recording, presentation slides and speaker audio from the event are available on the FST website: **www.foundation.org.uk/Events/2023/Mission-Zero-Getting-to-Net-Zero-by-2050**

A mission to deliver net zero

Chris Skidmore

The Rt Hon Chris Skidmore OBE has been MP for Kingswood since 2010. He served as Universities and Science Minister twice between 2018 and 2020, as well as spending a period as a Minister in the Department for Health and Social Care. He is a member of the House of Commons Environmental Audit Committee. In September 2022, he was asked to chair the Net Zero Review, the report being published under the title *Mission Zero*.

SUMMARY

- The UK's efforts on net zero are front-loaded and need to be achieved in the next five years
- A mission-based approach will help the UK deliver net zero
- Delivering net zero requires a 'whole society' approach to policy making
- Economic success for the UK will come in designing green solutions for the world
- A political consensus is needed to reach our goal.

It is important to recognise that net zero is not just about 2050. There is a tendency to think of it as a 28-year project, but when we come to look at the politics and the decisions about implementation of net zero, it is clear that the choices we make in this decade – indeed, in this year – will determine whether we meet our national determined contribution, or NDC, that was set at the Glasgow climate pact.

Now, had someone told me back in 2019 that 90% of the world's GDP would now be subject to net zero targets, I simply would not have believed it. There has been enormous progress, both in the UK and internationally. For most countries to achieve net zero, whether in 2050 or 2060 (or 2070 for China), they must meet the targets they have set for 2030 or the project will unwind.

'Net zero by 2050' was not a target set in isolation, it was established in order to limit global temperature increase to 1.5˚C. The IPCC has concluded that the likelihood of reaching that target is now small. We have up until the middle of the next decade, at best, to maintain that target. So the policy debate on net zero is real and present.

The UK has one of the most ambitious NDCs: 68% emissions reductions on 1990 levels by 2030, and 78% by 2035. Much of the work has been front-loaded and will need to be achieved in the next five years. That is why the review[1] argues that the UK should not fall behind in the race to net zero. The Inflation Reduction Act was signed in the US during the period of the review and it has created an entirely new paradigm, a new narrative. Even if there were no climate crisis, we should be taking these steps anyway, just for the opportunities it provides for the UK's future. There is no future economy that is not also a green economy.

Politicians like US President Joe Biden recognise that, in the future, every second job will be a green job. Increasingly, green jobs are mainstream: they are engineering jobs, science jobs, retrofitting jobs, and a host of other mainstream jobs that anyone could aspire to.

The review's terms of reference were to look at how the UK can achieve net zero in a more affordable and efficient manner, one that is pro-business and pro-growth. If we over-promise and under-deliver on the initial targets set for 2030 and beyond, how will the public trust politicians to deliver in the future? So there is a lot riding on our ability to deliver on our targets in the short to medium term.

In drawing up the report and its conclusions, we decided to take a mission-based approach, which allows us to provide the long-term policy certainty needed for a transition that is more affordable and more efficient. If we want to de-risk the cost of capital and investment, bring down the cost of developing and implementing technology, reduce labour costs for the supply chains, we must commit the upfront investment sooner rather than later, as delay only adds to the cost of delivery.

The impact of 'not zero' is not just the loss of

economic benefit by not being a leader in future climate technologies like hydrogen, CCUS and new nuclear, but failure to act on mitigation will impact on adaptation for the future and result in huge cost to the UK. So the review set out a paradigm of certainty, clarity, consistency and continuity: four 'C's that will define our missions. We set out ten 10-year missions that will begin in 2025. This is the midway point towards 2050, five years from the NDC for 2030. While we should continue where we have already been very successful – such as with offshore wind – the primary mission must be around grid and infrastructure.

Net zero is not just the responsibility of central Government, though. Some 50% of all net zero decisions will need to be made outside of Government, which will require a 'whole society' approach to policy making. Local and regional authorities, in particular, need greater powers and responsibilities in order to deliver the greatest impact as quickly as possible.

Of course, 2050 is the overall UK target. Scotland has chosen 2045, Wales and Northern Ireland have 2055. But then, Manchester wants 2038 while Bristol, Oxford, Cambridge and other cities are powering further ahead. Now, internationally, most countries are off track on their NDCs, but of 40 of the world's big cities, the majority are on track to deliver their net zero commitments by 2050. So we should empower those who are able to go further and faster, while at the same time working closely with those who need additional support and investment. There are hard-to-abate areas, countrysides with agricultural impacts, industrial areas with historic carbon-intensive industries.

So the review proposed a 10-year mission approach for a number of sectors. I am particularly keen to focus on solar, because I believe a 70 gigawatt target for 2035 is achievable. Net zero is not about continuing down the same path as before. We must work out how to utilise demand better, treating energy as a service rather than a commodity.

Crucially, we must empower individuals to take their own net zero journey. I meet many people who have put solar panels on their roofs, who have bought electric vehicles – and they have never looked back. With the rising cost of energy, net zero has become far more than just an environmental project. It is also now a question of energy security.

There is a delicate political tightrope when it comes to transition, all of our policies are in transition as well. Many of the existing policy frameworks are not fit for purpose when considering the challenges involved in delivering net zero over the next two and a half decades. The planning system, for example, will need to be changed. Take the new coal mine planned for Cumbria which undermines international UK climate leadership. Had there been a climate compliance test in the planning system, it would not have got through. Energy Performance Certificates are also not fit for purpose in terms of encouraging carbon reduction.

So we need to create new frameworks as we go on our journey – but we also need to rely on our existing policy frameworks to maintain the accountability mechanisms in tracking commitments and adherence. It will not do to promise savings 'tomorrow' or 'in 2050'. It is not possible to achieve the goal in 2050 but not make progress towards reducing over half the emissions by 2030. That reality has been set out by the UN, by the IEA and in Catherine McKenna's recent *Integrity Matters* report. It needs to be emphasised from the top of Government, down through business and into wider society.

Another feature of a long-term mission-based programme is a move away from the project-by-project approach which has been endemic of the UK Government's approach so far. Germany has a 10-year programme for delivering energy efficiency. In contrast, the UK's initiatives have a stop-start, concertina nature that just ends up costing more in the longer term.

The US Inflation Reduction Act is a $369 billion investment in green technologies. Instead of decrying it, we should work out how to create a new special relationship, working together on some of the really effective global solutions to the net zero challenge. And the economic success for the UK will come in designing global solutions, not just UK based solutions for UK based problems.

The *Mission Zero* review has been written in a way that has tries to help the Government move forward. It includes a framework of immediate actions that can be taken forward before the next general election. The missions then feed in from 2025: we must get the infrastructure (grid capacity, capability, storage issues) in place first before we can deliver on our net zero goals.

Delivering on our 2050 aim means cementing a consensus among the different political parties that was there when the *Climate Change Act* was signed into law back in 2008, and in 2019 when the target was raised to 100% emissions reductions on 1990 levels. A consensus is needed for the next general election, on taking forward the recommendations of the review.

The next general election will be fundamental to tackling climate change in the UK. It will be the next administration which will be responsible for delivering on the NDC by 2030. □

DOI: 10.53289/GTLL1854

[1] www.gov.uk/government/publications/review-of-net-zero

Net zero is not just the responsibility of central Government. Some 50% of all net zero decisions will need to be made outside of Government, which will require a 'whole society' approach to policy making.

With the rising cost of energy, net zero has become far more than just an environmental project. It is also now a question of energy security.

Priorities for creating a decarbonised world

Adair Turner

Lord Adair Turner chairs the Energy Transitions Commission, a global coalition of companies, NGOs and experts working to achieve a net zero economy by 2040. He is Chairman of insurer group Chubb Europe and on the Advisory Board of Board of Shanghai energy group Envision. From 2008-2013, Adair Turner chaired the Financial Services Authority, leading the redesign of global banking and shadow banking regulation. He chaired the Climate Change Committee from 2008 to 2012.

SUMMARY

- Annual investment in green technologies will need to more than triple to $3.5 trillion in the next decade
- Electricity systems across the globe will need to be substantially expanded
- New distribution and transmission networks must be planned ahead, rather than built reactively
- Balancing supply and demand for electricity is a major challenge around the world
- Decarbonisation could create hundreds of thousands of new jobs in the UK alone.

The work of the Energy Transitions Commission is global, so it is as much concerned with how China or India decarbonises as Europe or the UK. It has recently produced a report on finance to support the transition to net zero across the world[1]. The headline is that current investment of about $1 trillion per annum in different green technologies will have to rise to $3.5 trillion by 2030 and be maintained at that level, before slowly declining in later decades.

Of that, $2.4 trillion, or 70%, is investment in the power system: 40% in power generation and 30% in grids, transmission and distribution. It is easy to lose sight of the absolute centrality of building a much bigger and entirely zero-carbon electricity system: that is fundamental to all paths to net zero.

In some countries, such as Indonesia or India, the electricity systems will have to be up to eight times bigger than today. Our scenarios suggest global electricity production and consumption increasing from about 27,000 terawatt hours today to 90,000TWh or more by 2050. Developed countries will also see very significant growth in the electricity system. In the UK, an increase from 300TWh of consumption today to 600-700TWh or more can be expected by 2050.

The UK electricity system of the future may have a role for nuclear as baseload, perhaps providing 20% of the total. Offshore wind will be essential, because once in place, it supplies power for 5000-6000 hours per year on average. Solar, on the other hand, will only give 1500-2000 hours production per year in the UK.

The UK has a clear target of 50GW of offshore wind capacity by 2030: that could produce as much as 250TWh. This is likely to rise to 70GW by 2040. Now targets matter: it is important to establish Government targets for major infrastructure like offshore wind at least 10 years ahead, as this allows supply chains to develop based on market certainty.

It is vital to have a clear strategy and to remove barriers that impede the speed of transition. The planning and permitting system is a case in point. That does not mean abandoning necessary environmental standards. However, it does mean making systems smarter, so that it does not take 11 years to deliver an offshore wind farm, for instance. Some of the most important challenges in electricity systems across the world and in the UK are not actually in generation itself. Often, the issues are to do with grids and balancing. A recent report estimates that 1000GW of renewable capacity is waiting for grid connections across the US and Europe.

A big challenge across the world is how to balance supply and demand of electricity over days, weeks and months when the wind does not blow or the sun does not shine.

Grid capacity

The UK has the same problem. Grids are not being built fast enough to deal with new generation and new sources of demand such as heat pumps or electric vehicle charging. Ofgem must be given a mandate to regulate both distribution and transmission grids in a way which supports the transition to net zero. To do this, we must allow investment in grids ahead of demand rather than reactively.

Another big challenge across the world is how to balance supply and demand of electricity over days, weeks and months when, for example, the wind does not blow or the sun does not shine. In some places, the answer will be batteries. In places like India where the vast majority of the electricity capacity will come from solar, the key balancing challenges are diurnal rather than seasonal. Day/night batteries will play a major role in enabling air conditioning after the sun has gone down.

In the UK, the problem is very different. It is essentially about the variability of wind. As we

develop more and more offshore and onshore wind as well as solar, renewables will eventually be providing around 70% of all our electricity. Yet there are two- or three-week periods when wind can drop significantly in the North Sea due to a blocking anticyclone over northwest Europe. This typically occurs just at the time when we have cold weather and electricity consumption goes up. A few months ago, between December and January, there was a period of cold, dry, windless weather. This was followed in January by an absolute bonanza of wind.

National strategic plan

So the UK needs a national strategic plan to deal with that challenge. We may continue to need a large bank of gas turbines for this although whether they will run on hydrogen, or on natural gas with carbon capture and storage, is still to be decided. Whichever is chosen, the UK will need storage capacity either for CO_2 or for hydrogen. Therefore, as a priority the UK needs to investigate geological storage capabilities and the ability to repurpose our gas reservoirs.

In the Commission's finance report, the second most important element was $500 billion for buildings. In the developing world, this fundamentally involves getting them 'right first time': well-insulated with good heating, ventilation and air conditioning systems (HVAC), etc. In this country it is primarily a retrofit challenge, albeit a substantial one. There are 28 million households in the UK, 23 million of which have gas boilers and each household will have to make a decision on what they are going to do in future.

Although it is common to talk about the hard-to-abate sectors of the economy being shipping or aviation or steel or cement, I have increasingly come to believe that the hardest to abate sector is actually residential homes. In the global steel sector, if the 50 top steel companies agree to do something it will happen. That is a much easier implementation challenge than getting 28 million households to make common decisions.

What is the solution? In the UK, if we go down the electric route, we will have to install one million heat pumps per annum for the next 15 years to end up with a decarbonised residential heat system. That in itself will require a much more strategic approach to finance.

It will also require a strategic approach to skills development. The Climate Change Committee in a recent report highlighted the huge job opportunities for plumbers, electricians and insulation installers needed to create a zero-carbon housing stock – some 200,000 extra jobs.

Yet those extra jobs are not going to appear immediately. The heat pump market is a seller's market not a buyer's one at the moment.

PIXABAY / ROMAN GRAC

The output of wind turbines can drop significantly because of weather patterns, just when electricity demand rises.

In many sectors of the economy, in particular industry, a clear and rising carbon price is a vital policy tool. But to make sure that carbon prices do not disadvantage carbon-intensive industries there must also be a coherent border carbon-adjustment mechanism, and here the UK's approach should mirror as closely as possible the mechanism being put in place by the EU: without such a mechanism, there will not be a single steel plant operator left in Europe. Most companies operating in the UK want to be able to operate in Europe as well and will want a standardised system.

I am convinced that, at the global level, if we focus on the energy, building, industry and transport sectors of the economy, we will get to something pretty close to a net zero global economy by 2050 in the developed world and 2060 in most of the developing countries. Technologies will get us there.

But frankly we wasted 15 years after we really understood the challenge. The Stern Report on the global economics of climate change, and the UK Climate Change Act of 2006 were huge steps forward . But after the financial crisis of 2008, political focus switched to other issues and the Copenhagen Climate Conference of 2009 ended with a major setback to global progress. We wasted a great deal of time: we are behind where we should be, and we now need to catch up fast. □

DOI: 10.53289/MPTB5264

[1] www.energy-transitions.org/publications/financing-the-transition-etc

Ensuring a liveable and sustainable future

Emily Shuckburgh

Prof Emily Shuckburgh OBE, Director of Cambridge Zero, is a climate scientist and mathematician, a Fellow of the Cambridge Institute for Sustainability Leadership, an Associate Fellow of the Centre for Science and Policy, and a Fellow of the British Antarctic Survey. She is also Professor of Environmental Data Science at the Department of Computer Science and Technology. She leads the UKRI Centre for Doctoral Training on the Application of AI to the study of Environmental Risks.

SUMMARY

- There is a "rapidly closing window of opportunity" to address climate change effectively
- With increasing scientific understanding comes the realisation of higher risk at lower temperatures
- There are feasible, effective and low-cost options for mitigation and adaptation already available
- Fairness is a concept that must be at the heart of any net zero transition
- The decisions we make today will reverberate for hundreds, perhaps thousands, of years.

The most recent 6th Assessment Report from the Intergovernmental Panel on Climate Change (IPCC)[1] states quite clearly that "there is a rapidly closing window of opportunity to secure a liveable and sustainable future for all". That is a striking and unequivocal message from the IPCC. It sets out the stark scale of the threat and the way the climate challenge really does permeate everything. It then describes with clear evidence how human-induced climate change is already affecting many workers during climate extremes in every region across the globe.

Every new cycle of the IPCC assessment catalogues the increase in scientific understanding since the last one. One of those areas of increased understanding concerns the interconnectedness of different risks and, in particular, how climatic change can have knock-on effects in other spheres. Last summer, the UK experienced record heat of 40˚C and there was a direct impact on lives, particularly of the elderly who are particularly vulnerable to extreme heat.

There were severe floods in Pakistan. Our understanding of the interconnected nature of climate-related threats means that we see not just the direct impact of those floods, which caused some 1500 deaths and $30 billion worth of damage in Pakistan, but also the associated impact elsewhere, in terms of food security (Pakistan provides about half of the rice consumed in the UK each year), and the displacement of tens of millions of people. Each year, something like 25 million people are internally displaced within their regions as a result of climate events. That in turn drives migration and also conflict. So climate-related changes can exacerbate other threats.

Figure 1 is one of the critical illustrations in the Synthesis Report. It is a standard figure that has been used in the last three IPCC assessment cycles. It is entitled Reasons for Concern, but it is also known as the 'burning embers' diagram. It looks across key indicators of the global system and the threats to it. It captures the level of risk at different levels of warming. It compares these different key indicator areas between the 5th IPCC assessment report, which came out in 2014, and the most recent one, almost 10 years on. Importantly, the 5th Assessment was issued prior to the Paris Agreement, in fact it fed into the negotiations. It is clear from the comparison that our understanding of the risks today is significantly greater. The diagram also shows there are much higher risks associated with lower levels of global warming than was understood at the time the Paris Agreement was written. That has implications for the level and speed of mitigation required.

The pathway that is required from today, if we are to limit the warming to 1.5˚C with a reasonable chance of success, looks like going over a cliff edge.

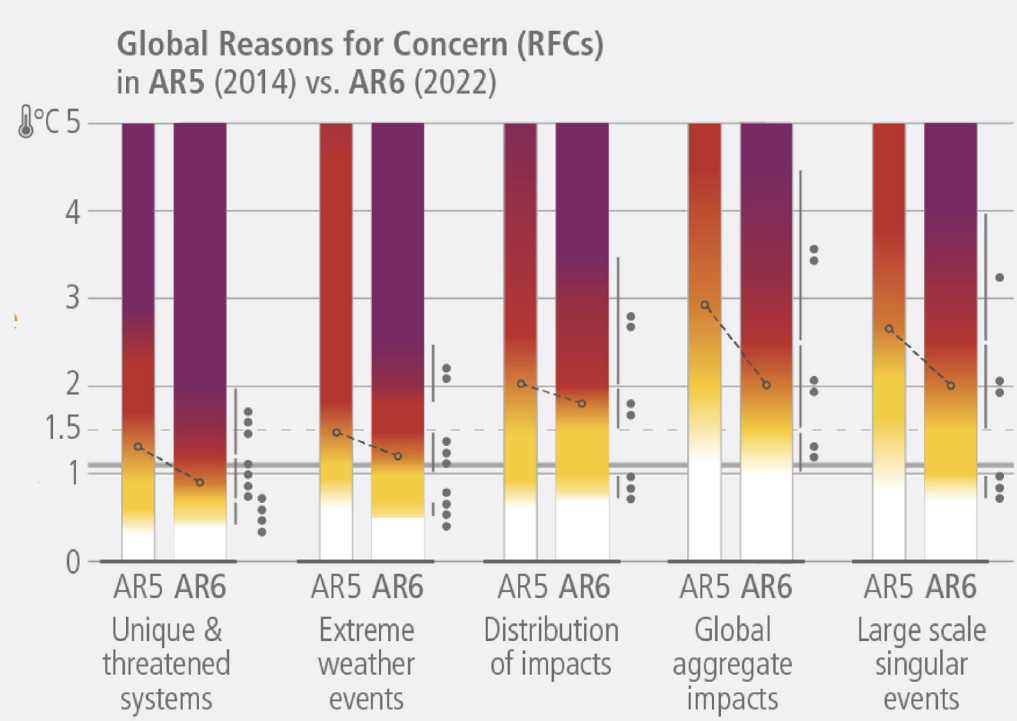
Rapid action

The other key statements from the Synthesis Report include the conclusion that limiting warming involves rapid and deep – and in most cases, immediate – greenhouse gas emissions reductions across all sectors. The emphasis is on action this decade. If we had had this level of understanding when the warning was first raised around climate change, we might have an easier task on our hands today.

The pathway that is required from today, if we are to limit the warming to 1.5˚C with a reasonable chance of success, looks rather like going over a cliff edge. It is a real challenge.

However, the other key message from the report is that we should not give up hope. There are feasible, effective and low-cost options for mitigation

Figure 1. Global reasons for concern in AR5 and AR6



(Source: IPCC)

The response to climate change has to be immediate but many techniques for mitigation and adaptation are already available.

and adaptation already available. And adaptation is critical as well as mitigation – it is sometimes forgotten. Another feature of the report is the greater understanding of co-benefits from reductions, particularly those associated with health through, for example, improved air quality.

There is of course a great deal of work across the world into green technologies to address climate change. At Cambridge, for example, we are looking at battery technologies which are essential to a zero carbon future, whether for electric vehicles, or storage, including grid scale options. The response to climate change requires the creation of a new way of living and the technologies being developed today will help make that future possible.

The IPCC has set out some of the critical elements that are required to support that transition at a global scale, but they are just as relevant at a UK scale. I was really struck by how much similarity there was between the statements in the Synthesis Report and the language of the Mission Zero review.

One is that tried and tested options available now need to be made to work in diverse contexts. A systems-based view of the challenge, with systems-based thinking embedded in the design of policies and regulations, will provide support for that net zero transition.

Any transition must, however, embody the concept of fairness. This is highlighted strongly in the IPCC report, but also, for example, in the Citizens Assembly that was held in 2020 in the UK. It is absolutely central, not only for an effective, widely accepted net zero transition, but also because net zero is impacting a world where we are seeing increased inequalities. Ensuring that we are actually helping to alleviate those inequalities through our net zero transition is crucial. Fairness also feeds into the skills agenda in context of new green jobs.

Policy cohesion

Another common thread between the IPCC report and the Mission Zero review is the need for integration and cohesion across policies at different levels of Government, in the UK through local councils and the devolved administrations through to national Government, aligning as well with international efforts. There also needs to be cross-Government interconnectivity.

Finally, we should never forget one of the key messages from the IPCC report: our choices today will reverberate for hundreds, even thousands of years. What we do today will affect generations to come. □

DOI: 10.53289/ZRBV1585

[1] www.ipcc.ch/report/ar6/syr

Our choices today will reverberate for hundreds, even thousands of years. What we do today will affect generations to come.

The debate

After the formal presentations, the speakers joined a panel to answer questions from the audience on a range of topics including: decarbonising housing; new technologies for heating buildings; reduction timings; methane and nitrogen taxes; and tipping points.

Decarbonising the housing sector is a critical challenge for the UK. Technology will be very important for this but it is not sufficient of itself. There is a combination of other more social factors too. We need to put in place measures to encourage behavioural change. Then, we also need the skills that are necessary to support the transition in our housing stock. To manage that diversity of factors successfully, a systems-based understanding is so important.

Improvements

Improving the energy performance of the whole of the UK housing stock to Scandinavian levels is never going to happen. Significant improvements are possible, though, combined with other mechanisms to produce a total effective result. There are also many interesting technologies emerging such as infrared heating which is designed to heat the person rather than large areas of empty space.

Getting to net zero by 2050 or 2060 is, paradoxically, getting easier. But a 40% reduction by 2030 is becoming close to impossible. So the end point is still inside the IPCC target and, indeed, is almost more likely than five years ago because of the extraordinary progress in some of the technologies – solar PV, wind, batteries, electrolysers and hydrogen.

Geoengineering is once again being raised as a potential solution – or partial solution – to the issue of climate change. It is incredibly difficult for a world of different nation states to coordinate targets and drive down emissions fast enough to limit global warming. Shading out the sun and reducing sunlight would seem to be politically impossible but more localised initiatives like increasing the CO_2 absorption of soil might be more achievable.

It should be possible to have methane taxes and nitrogen taxes in the same way that carbon is taxed. It will be more complicated because while it is quite easy to work out how much CO_2 is being emitted, the exact amount of nitrous oxide which is emitted by the application of nitrogen based urea and other fertilisers, is much less certain.

In an environment where there are dangers of a number of tipping points being triggered by short term temperature increases, which in turn make future long-term temperature increase even more likely, it is imperative to act quickly and with a sense of urgency. □

FURTHER INFORMATION

IPCC (2023) AR6 Synthesis Report – Climate Change 2023.
www.ipcc.ch/report/ar6/syr/

Energy Transitions Commission (2023) Financing the Transition
www.energy-transitions.org/publications/financing-the-transition-etc

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www.un.org/sites/un2.un.org/files/high-level_expert_group_n7b.pdf

Mission Zero
www.gov.uk/government/publications/review-of-net-zero

FST PODCASTS

Reaching Net Zero Globally –with Lord Adair Turner, Chair of the Energy Transitions Commission
www.foundation.org.uk/Podcasts/2023/Lord-Adair-Turner-Mission-Zero,-Getting-to-Net-Zer

The Integrated Review described the ambition for the UK to become a science superpower. This has prompted much debate on what that means and how it can be achieved.

Strategic Advantage through Science and Technology

Frances Saunders

The Integrated Review of Security, Defence, Development and Foreign Policy[1], published in March 2021, headlined the twin ambitions for the UK to become a scientific superpower by 2030 and to adopt a more proactive approach to building and sustaining strategic advantage through science and technology.

Since then, much has changed in Government including the launch of the new Department for Science Innovation and Technology (DSIT). In parallel, there has been much debate within the research, innovation and engineering communities about what those stated ambitions might mean in practice. The Royal Academy of Engineering has contributed to those debates and has published an engineering viewpoint on what we mean by strategic advantage, together with the key ingredients and actions we believe are necessary for that ambition to be pursued successfully[2].

For those of us who have worked in defence and security, the identification of S&T capability areas, which are critical and where 'ownership' is important, is not a new challenge. Over the years there have been many reviews and lists of such critical technologies assembled. These were often contentious, as technology advocates aimed to get theirs on the list while those who assembled the list tried to focus on technologies where independence was critical. They recognised, rightly, that it would be unaffordable for the UK to have a sovereign capability in every technology that might contribute to the achievement of strategic advantage.

The Integrated Review also acknowledged this dilemma. It noted that in some areas the UK would have to collaborate in order to gain access to the leading edge of a technology. In others, it would have to rely on countries who had greater capability. These 'own, collaborate or buy' decisions are extremely complex and the resulting reliance on others potentially uncomfortable.

They also require leadership and active decision making, rather than the benign neglect that has seen the UK lose important capabilities in the past (particularly in production engineering and manufacturing) without realising they were slipping away until it was too late. It is also the case that the choices inherent in collaboration or in buying technology are not without costs and risks.

To collaborate and partner with others presupposes you have something to offer that your potential partner values equally highly, or else it will not work. Buying in technology, on the other hand, demands that you still have the absorptive capacity and skills necessary to specify and assess what you are buying and then experiment with how to use it, so that it delivers the benefits you require.

Reliance on others also affects resilience. International shocks, such as those caused by Covid or the war in Ukraine, can disrupt access when worldwide demand exceeds supply, or politics intervenes.

Complex issues

With the complex set of issues that identifying and managing critical technologies entails, it is obvious that Government needs to do more than just publish a new list periodically. It must also lead planning for the long term and then stick to the direction it sets.

Long term in this context also means 'beyond five-year political cycles': longer-term budgets can override Treasury annual demands, will result in more durable institutions but will not lend themselves to so many short-term announceable initiatives.

Cross-party engagement and adoption of this agenda would also help achieve the necessary stability to enable the Research and Innovation (R&I) system to deliver. It would provide the confidence needed for businesses to invest and thrive. This call for longer term stability does not mean being unresponsive to emerging challenges or lacking the agility to capitalise on new opportunities. Rather, it implies having a more stable environment which creates a platform of well-connected people and capabilities that can respond rapidly when such a response is needed.

So, what more does it take to 'own' a technology

Dr Dame Frances Saunders DBE CB FREng HonFInstP chaired the Royal Academy of Engineering Working Group that produced the report: *Strategic advantage through science and technology: the engineering view*. She was the chief executive of Dstl from 2006-2012. She now undertakes a portfolio of science and engineering advisory work including chairing boards for the Cockcroft Institute and Photonics Manufacturing and Quantum Technology Hubs. She was a member of the REF 2021 Physics Panel and was President of the Institute of Physics from 2013-15.

With such a complex set of issues, it is obvious that Government needs to do more than just publish a new list periodically.

There is a compelling case for the public sector to provide support to manage the risks associated with late-stage R&D and market creation.

and harness the strategic benefits that are on offer? This is where taking a systems approach is of critical importance. It must start with an honest appraisal of the current UK strength and competitiveness in that specific technology. There must be an objective view of the challenges that will arise in the end-to-end process of taking it from basic research, through the different Technology Readiness Levels (TRLs), up to late-stage R&D and then on to adoption, scale-up and delivery of the promised benefits.

What is often missing at an early stage is a realistic, quantitative assessment of the potential benefits to industry and end-users that the technology can deliver. This can be used to create some performance targets to aim for that will make all the later stage challenges and risks worth the effort and the investment.

This is also the time to start considering whether there are any potential downsides, or risks, from pursuing the technology. These conversations need a connected community of Government, academic researchers, industry, beneficiaries and wider stakeholders in the technology. Together, they can provide both expert advice and can support planning to address the notorious valley of death into which so many efforts to take technologies up the TRL ladder continue to fall.

Enabling technologies

Often missing from such discussions are the other enabling technologies that need to be accessed, or optimised, in order to push forward later-stage R&D, integrate the technology into engineered systems and then manufacture them. Specific issues like size, weight and power have to be addressed at some stage to move from proof-of-concept prototypes to well-engineered products.

Building the confidence that performance targets are achievable may also require access to infrastructure such as simulation, digital twins and testbeds. Of course, roadmaps of how a technology needs to develop and the factors that will enable its success can be problematic. Sharing the thinking, and the tacit intellectual property, that roadmaps include can be commercially sensitive.

Nevertheless, it is worth considering how to share as much intelligence as possible and whether industry/university consortia can sometimes work pre-competitively to get the technology to a particular TRL where all can share the benefits. From there, the programme can go on to accelerate and scale up by building on that platform of shared knowhow. This may be even more important where the benefits are to wider society in areas such as the environment and healthcare.

The fact that Government has moved to a point where it sees Science and Technology as central to the delivery of its policy agenda must be good news. However, beyond that recognition and positive statements of its intentions, there is much still to do to change mindsets and long-held norms. Only then can such an innovation policy become integrated into all Government Departments as a priority and DSIT is not left alone holding the baby. Coherence of approach across Government is also a priority in building confidence in the R&I system so that the rhetoric will stick and be actioned.

Intervention

Where and how Government intervenes in the lifecycle of technology development, adoption and deployment also needs to be challenged. Government gets increasingly uncomfortable in supporting technology as it moves up in TRL. However, there is a compelling case for the public sector to provide more support to manage the risks associated with late-stage R&D and market creation – the socio-economic benefits from the new products, processes, services and technologies are shared, so the risk must be too. This case is arguably stronger when in pursuit of strategic advantage and in the face of interventionist global competition.

We now have an updated list of five critical technologies set out in the March 2023 S&T Framework. The promised publication of a long-term plan for each technology is well underway, with strategies for quantum, semiconductor and wireless infrastructure produced so far. However, this is just the start and will not effect change if there is no adoption and buy-in to the approach by the R&I community at large.

Action means intervention. Having signposted an overall direction, there will still be choices to be made: about where and how best to pursue strategic advantage in the round and select between conflicts that might arise; about who will drive forward the resulting plans at pace; about how to manage the risks of collaboration or reliance on others; and about what skills will be required to support delivery. Then resources will need to follow. □

DOI: 10.53289/MXZD4321

1. www.gov.uk/government/collections/the-integrated-review-2021
2. https://raeng.org.uk/media/zxte0gxb/strategic_advantage_through_science_and_technology_the_engineering_view.pdf

MAJOR SUPPORTERS IN 2023

A

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

B

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

C

Canterbury Christ Church University
Chartered Institute of Credit Management
Chartered Institute of Plumbing and Heating Engineering
Comino Foundation
Cranfield University

D

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

E

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

G

Genomics England

H

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

I

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

J

Japan Society for the Promotion of Science
Johnson Matthey Plc

K

Kaizen UK Consulting Ltd (Kaizen Institute)
King's College London

L

Lancaster University

M

Matrix - The Northern Ireland Science Industry Panel
Medical Research Council, UKRI
Met Office

N

National Centre for Universities and Business
National Physical Laboratory
Natural Environment Research Council, UKRI
Natural History Museum
Nottingham Trent University

P

Parliamentary and Scientific Committee
Peter Jost Charitable Foundation

R

Research England, UKRI
Rolls-Royce
Royal Society of Biology
Royal Society of Chemistry
Royal Statistical Society

S

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

T

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

U

University College London
University of Bath, Institute for Policy Research
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