The Journal of the Parliamentary and Scientific Committee – All-Party Parliamentary Group

SCIENCE IN PARLIAMENT

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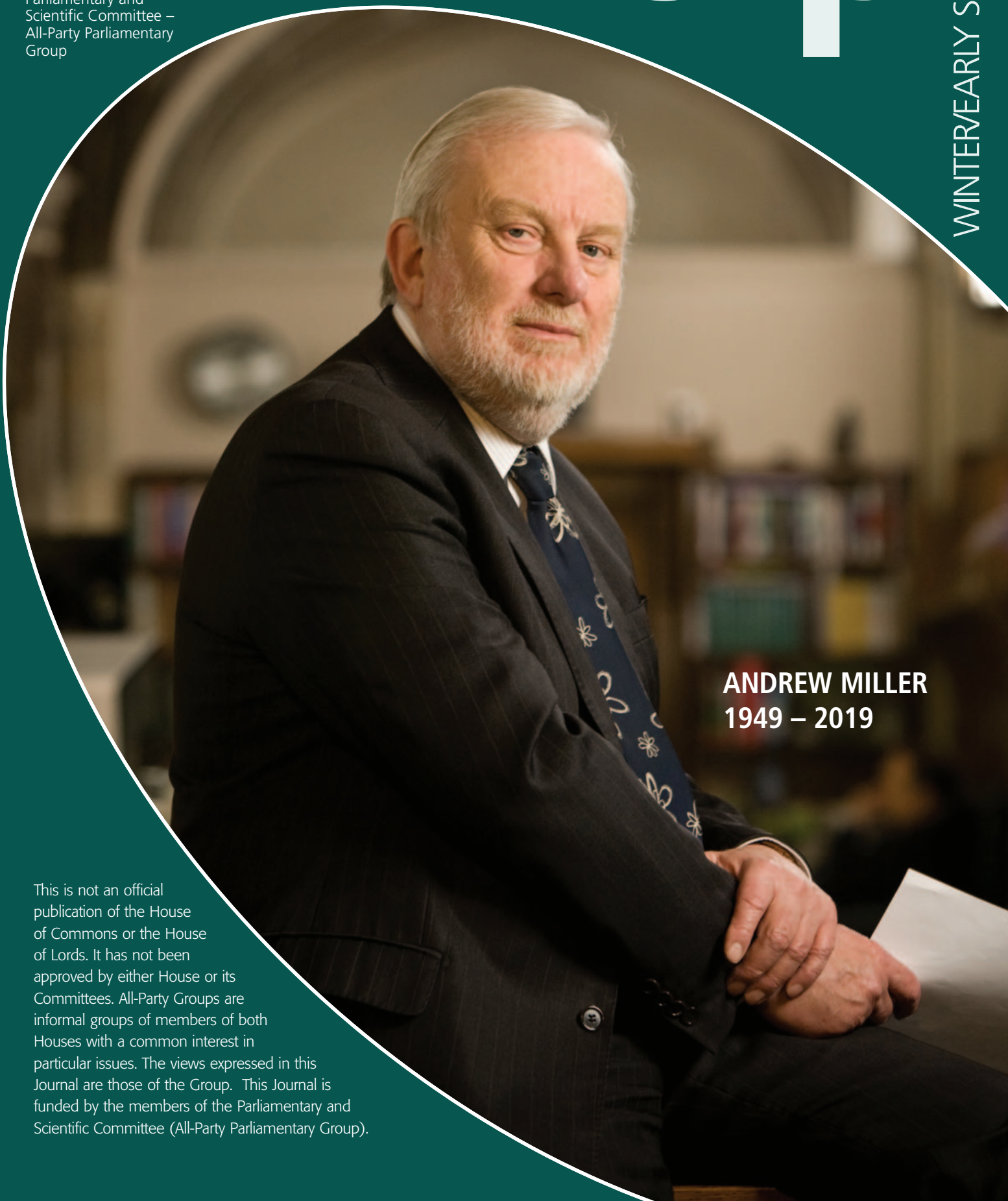
WINTER/EARLY SPRING 2020



ANDREW MILLER
1949 – 2019

STEM for BRITAIN

Parliamentary and Scientific Committee
Bringing Science and Parliament together

STEM for BRITAIN

Stephen Metcalfe MP and the Parliamentary and Scientific Committee would like to thank all those organisations supporting STEM for BRITAIN 2020; without you the event would not be possible!

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Stephen Metcalfe MP
Chairman, Parliamentary & Scientific Committee (All-Party Parliamentary Group)

A warm welcome to our first edition of 2020.

I was very pleased to have been elected to Parliament for the fourth time, on the 12th December, and subsequently re-elected as Chair of the Parliamentary & Scientific Committee at the Inaugural Meeting on the 13th January.

Congratulations to my fellow Officers, Lord Broers, Chi Onwurah MP, Carol Monaghan MP, Lord Willis of Knaresborough and others on their re-election. I am also delighted to welcome Chris Green MP to the Committee.

Just before this edition went to print, the results of the House of Commons' Select Committee Chair elections were announced. My congratulations, in particular, to: Rob Halfon MP (Education), Jeremy Hunt MP (Health and Social Care), Rachel Reeves MP (Business, Energy & Industrial Strategy), Neil Parish MP (Environment, Food and Rural Affairs) and Greg Clark MP (Science and Technology). We shall resume reports from these key Committees when they are fully constituted, along with those from the House of Lords.

Since the Inaugural Meeting the Committee has resumed its programme of meetings beginning with two excellent discussions on the topics of 'Smart Energy' and 'Noise, Sound and Accoustics', generously sponsored by UKRI and the Institute of Acoustics respectively.

Lord Broers

Dame Jocelyn Bell Burnell

The Annual Lunch, postponed from November, due to the General Election, was held in the Cholmondeley Room on the 21st January. It was hosted by the President, Lord Broers, who was delighted to welcome as our distinguished guest speaker, Dame Jocelyn Bell Burnell.

We look forward to STEM for BRITAIN, on the 9th March, in the Attlee Suite, Portcullis House, our prestigious annual competition celebrating the excellent achievements of early career researchers from across the U.K.

In this issue we have commissioned a brilliant array of articles and features covering a wide variety of topical subjects, which I am sure you will enjoy reading. My grateful thanks to each of our writers.

Amongst the contributions is an excellent tribute to the late Andrew Miller, from Dr Stephen Benn, Vice President of P&SC.

We will always remember Andrew, not only for his engaging and stimulating personality but also for his wonderful service as Chair of the Science and Technology Committee - the first MP to be elected to that position - and also as Chair of the Parliamentary & Scientific Committee.

Andrew contributed greatly to the understanding of science at Westminster and beyond. He will be very sorely missed.

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The Journal of the Parliamentary and Scientific Committee (All-Party Parliamentary Group).

Science in Parliament has two main objectives:

1. to inform the scientific and industrial communities of activities within Parliament of a scientific nature and of the progress of relevant legislation;
2. to keep Members of Parliament abreast of scientific affairs.

CONTENTS

The Journal of the Parliamentary and Scientific Committee (All-Party Parliamentary Group).

CLIMATE CHANGE – IS THERE A PLAN B? RESILIENT NATION 2
Prof Chris Rapley CBE

SCOTLAND'S ENERGY FUTURE 5
Craig Denham

CAN OBESITY GASTRIC SURGERY CURE DIABETES? 7
Mr Ali Alhamdani

"WHY THIS IS THE BEST WEIGHT LOSS SURGERY FOR YOU – WHAT I WOULD CHOOSE FOR YOU AS YOUR OBESITY SURGEON" 8
Mr Ali Alhamdani

HOW AI WILL TRANSFORM HEALTH: AND HOW IT WON'T 9
John Loder

GEOLOGICAL SKILLS AND KNOWLEDGE CRUCIAL IN DELIVERING NET-ZERO 11
Professor Mike Stephenson and Florence Bullough

ENGINEERING THE FUTURE OF THE UK 14
Professor Colin Turner PhD FIET FIMA PFHEA NTF

VISIT OF DELEGATION FROM GANSU PROVINCE, CHINA 16
Professor Ian Haines

ANDREW MILLER 1949-2019 18
Dr Stephen Benn, Vice President

THE CHALLENGES AND OPPORTUNITIES FOR UK-IRELAND COLLABORATION IN HIGHER EDUCATION AND RESEARCH POST-BREXIT 20
Professor Gerry McKenna MRIA

DIFFICULT COMPROMISES ON THE ROUTE TO ZERO CARBON FOR ELECTRICITY AND TRANSPORT 23
Lord Alec Broers

PARLIAMENTARY OFFICE OF SCIENCE AND TECHNOLOGY (POST) 26

SCIENCE DIRECTORY 26

SCIENCE DIARY 37

CLIMATE CHANGE – IS THERE A PLAN B?

RESILIENT NATION

Prof Chris Rapley CBE
Professor of Climate Science
University College London

Director of the British Antarctic Survey from 1998 -2007

Director of the Science Museum in 2007 – 2010

In 2008 he was awarded the Edinburgh Science Medal – "For professional achievements judged to have made a significant contribution to the understanding and well-being of humanity"

Since January 2014 Chris has been Chair of European Space Agency

Four years ago, at COP21 in Paris, the nations of the world committed to Climate Change 'Plan A'. They agreed to take actions to keep global warming to well below 2ºC relative to pre-industrial times, and as close as possible to 1.5ºC. To do so requires us to 'Leave it In the ground', where the 'it' corresponds to 82% of known coal reserves, 49% of oil reserves and 33% of gas reserves [1].

UNFORTUNATELY, PLAN A IS NOT WORKING.

CO_2 emissions in 2018 were a record 37 billion tons, corresponding to a 2% annual growth. Atmospheric concentrations are at a multi-million year high. The 2015-2019 five-year period is destined to be the warmest on record. The global average temperature rise is already +1.1°C above pre-industrial. Climate impacts are hitting harder and sooner than predicted. To achieve the Paris commitments would require a tripling to quintupling of current commitments [2]. Oil and gas companies continue to invest in discovering new reserves [3].

At issue is not just whether we can cope with the growing climate impacts, but whether or not we can remain masters of our destiny. The 2°C 'guardrail' was chosen to avoid triggering climatic Tipping Points. These include the collapse of the Greenland and West Antarctic ice sheets, irreversible changes in ocean and atmospheric circulation, the release of methane from the Arctic ocean and permafrost, and the die-back of the Amazon rainforest. There is a risk of a domino effect. Once started, the chain reaction would be unstoppable – we would lose control.

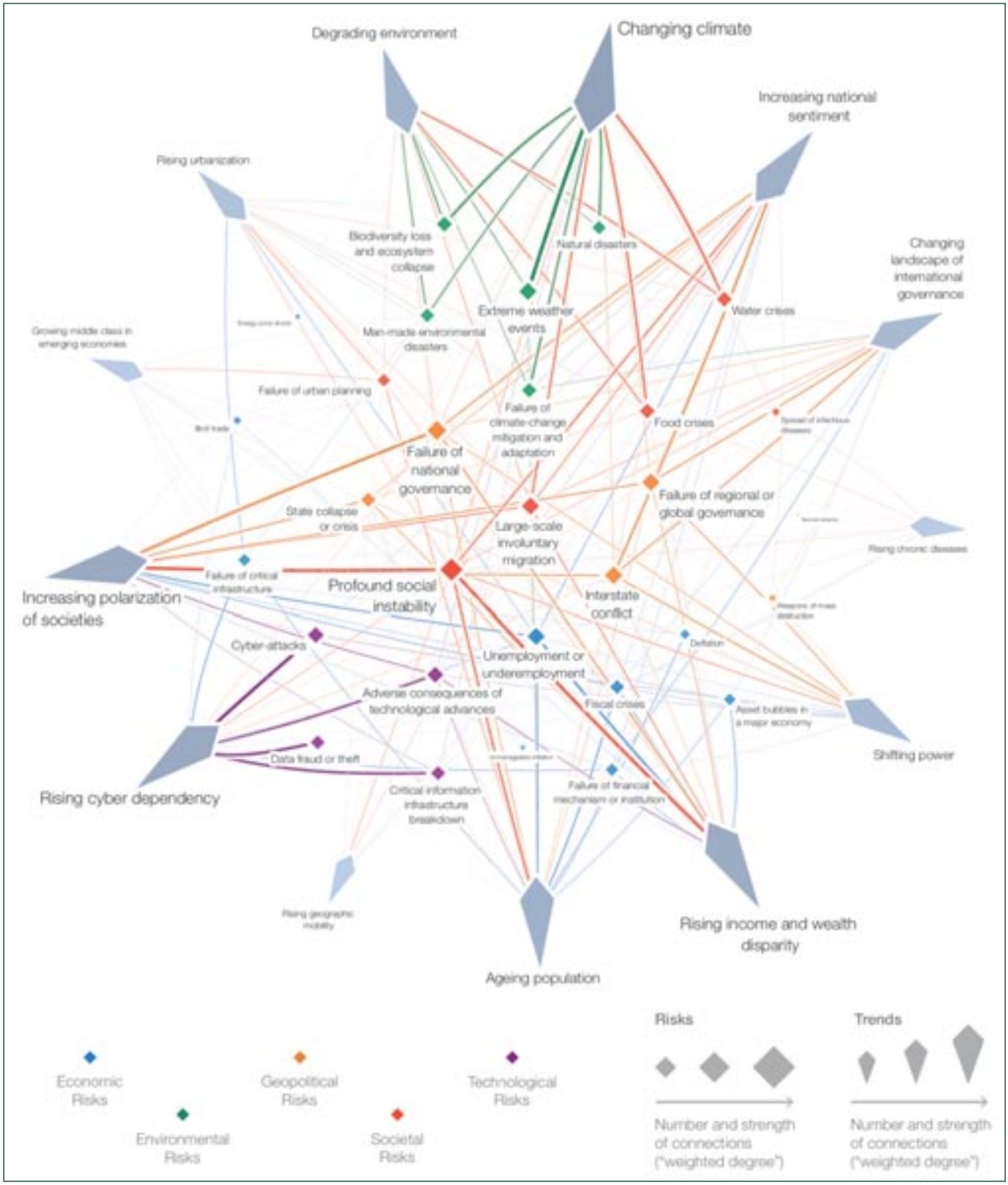
It is not clear in what state the system would ultimately settle [4]. But for a temperature rise exceeding ~7°C, significant areas of the Earth would become uninhabitable due to heat stress [5]. Combined with the disruption of water resources, the direct impacts of storms and wildfires, and the impacts of sea level rise, mass migrations of millions, if not billions, would follow (see for example Vinke et al [6]. In its 2014 Climate Change Adaptation Roadmap, the US Department of Defence observed *"Rising global temperatures, changing precipitation patterns, climbing sea levels, and more extreme weather events will intensify the challenges of global instability, hunger, poverty, and conflict"* [7]. They refer to climate change as a 'threat multiplier' - exacerbating problems in an already troubled world.

The military and security services are not alone in contemplating what might befall us. The World Economic Forum publishes an annual Global Risks report. In recent years, the threats identified as highest probability and impact are *'Extreme Weather Events'* and *'Failure of Climate Change Mitigation and Adaptation'* [8]. In their 'Risks-Trends Interconnections Map' (see figure) they illustrate how a combination of drivers, including climate change and forced migration, is driving the world towards profound social instability.

More specifically, in its 'Security Outlook 2030', the WEF sought to answer "What is the worst that can happen?" Based on a substantial multi-nation exercise, they present three possible scenarios: 'Walled Cities', 'Strong Regions' and 'War and Peace' [9].

'Walled Cities' may be characterised as follows:

- *Greater penetration of information and communications technology broadens the horizons of citizens in many countries, raising expectations in areas such as health, education, infrastructure and quality of governance*
- *Fiscal challenges and political dysfunction erode state provision of public services*



The Risks-Trends Interconnections Map (*from the WEF Global Risks 2019 Report* [8])

- *Citizens become disillusioned by their exposure to public sector corruption, poor service delivery and ineffective institutions*
- *Inequalities widen and middle classes are hollowed out*
- *Elites retreat to gated communities and turn to private sector for basic services*
- *Fertile soil, fresh water and even clean air become increasingly commoditized*
- *Society becomes increasingly polarized between elites and impoverished classes with little social mobility*
- *Rootless and disillusioned young people become anti-system and vulnerable to radicalisation*
- *States lose ability to cohere people around a shared narrative or identity*

- *Insurgencies, terrorist groups and criminal organisations exploit the security deficit*
- *The world divides into islands of order in a sea of disorder*
- *As large numbers of people are displaced by climate change and social violence, still-functioning states seek to protect themselves*

The upshot is a 'World of Walls', in which nation states adopt a 'Fortress' mode. Interestingly, when the Berlin Wall fell in 1989 there were 15 border walls worldwide. Today there are 70. Examples include the 3m high partly electrified barbed wire fence that runs along 70% of the 4,100km border between India and Bangladesh, and President Trump's plan to complete the isolation of the 3,200km border between the USA and Mexico. The trend is already well-established.

'Strong Regions', envisages a volatile and competitive but stable world with several seats of power. Overwhelmed by mistrust, governments invest their political, financial and diplomatic capital in bilateral or regional processes. In 'War and Peace' the world drifts into a major conflict which ultimately leads to a transformational reworking of the global system.

The WEF emphasise that the scenarios are not predictions, but plausible trajectories. They are useful to challenge current thinking, and to serve as a call to action for the development of more adaptable and resilient response systems. In all three cases, however, an inescapable conclusion is that for nations to remain viable, a high degree of self-sufficiency will be critical.

Responsible and prudent governance should therefore seek to ensure the robust health of key national capabilities such as agriculture, water supplies, energy production, information technology, transport infrastructure, raw material access, industrial production, pharmaceuticals, skills production, and defense.

In practice, the state of play and direction of travel in the UK are not encouraging. Food security has declined from 78% in 1984 to ~60% in 2018 [10]. The steel industry, following a period of overseas ownership, has been allowed to collapse. The defense of off-shore wind farms is hard to achieve in principle, and virtually impossible in practice, given the nations' current military assets. In an age in which digital information flows are crucial for effective societal organization and governance, a reliance on Chinese communications technology is arguably deeply unwise.

The conclusion? No nation or individual will escape the looming impacts of climate change. In combinations with the other factors shaping our global collective future, profound social instability is a material risk. With this in mind, 'Resilient Nation' would be a wise precautionary strategy, and hence an appropriate and desirable Plan B.

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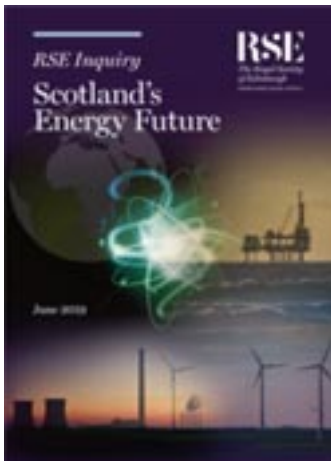
SCOTLAND'S ENERGY FUTURE

Craig Denham – RSE Policy Advice Officer and Inquiry Secretariat

The RSE Inquiry into *Scotland's Energy Future* was led by Sir Muir Russell, with Professor Becky Lunn serving as Deputy Chair. The full report, and contact details for the Secretariat, can be found on the Royal Society of Edinburgh website at www.RSE.org.uk/EnergyInquiry.



In June 2019, the Royal Society of Edinburgh (RSE) published its final report into *Scotland's Energy Future*. The report was the culmination of almost two years of work, undertaken with the intent of contributing to the debate about Scotland's energy supply, demand and use, while properly recognising Scotland's moral and environmental responsibilities against the backdrop of a changing climate and a need to reduce carbon emissions.

As Scotland's National Academy, the RSE is in the unique position of having access to a wide-range of expertise provided by some of the foremost experts in Scotland. Moreover, the RSE's status as a renowned, impartial, learned society allows it to utilise this experience and knowledge to produce a considered view of the issues Scotland faces regarding energy production, use, governance and the options that are available to Scotland to meet its energy needs.

The expert Committee undertaking the Inquiry came from a wide range of backgrounds and disciplines covering areas such as engineering, law, sociology, climate and economics, as well as energy.

The RSE took evidence in a variety of ways from hundreds of individuals, organisations and businesses from across Scotland and beyond. Written responses to a consultation were received, public engagement events were held around Scotland, roundtable discussions convened to discuss issues affecting different sectors, and meetings held with many stakeholders to ensure that the final report covered as much of the vast and complex area of energy policy as was possible.

THE FINAL REPORT

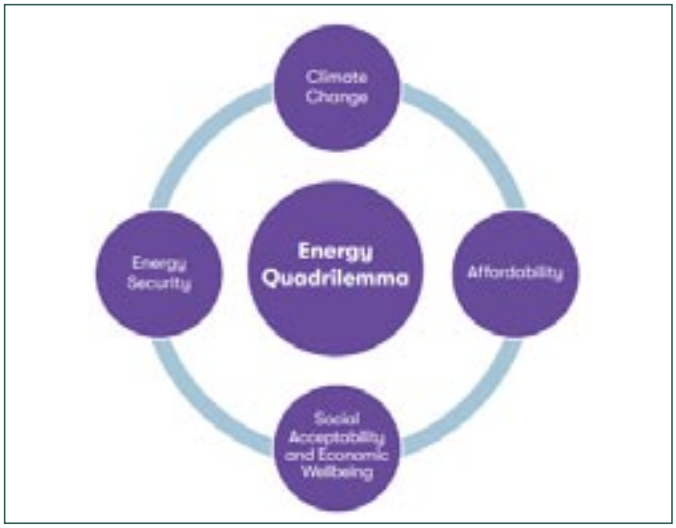
The final report serves as a guide to the energy landscape in Scotland, reviewing the governance of Scotland's energy system, analysing the context in which we produce and use energy and in which decisions will occur, and explaining the trade-offs that need to be made. The Inquiry report discusses the advantages and drawbacks of all of the options available to Scotland to meet its energy needs now and into the future, with particular attention drawn to the issues the expert Committee conducting the Inquiry considered to be most pressing.

Some of the options, for example the use of fossil fuels, are already a significant part of the energy mix, but have severe consequences for our climate and Scotland's ability to meet its carbon reduction targets. A decision to move away from carbon intensive industries, however, has significant impacts on jobs and communities and must be adequately considered and planned for.

Other options may provide the energy we need in a more carbon neutral manner but could also be some way from being viable at scale. Carbon capture and storage technology could potentially facilitate continued use of fossil fuels or support a transition to the use of hydrogen, resulting in lower carbon emissions. This would, however, require a high level of investment.

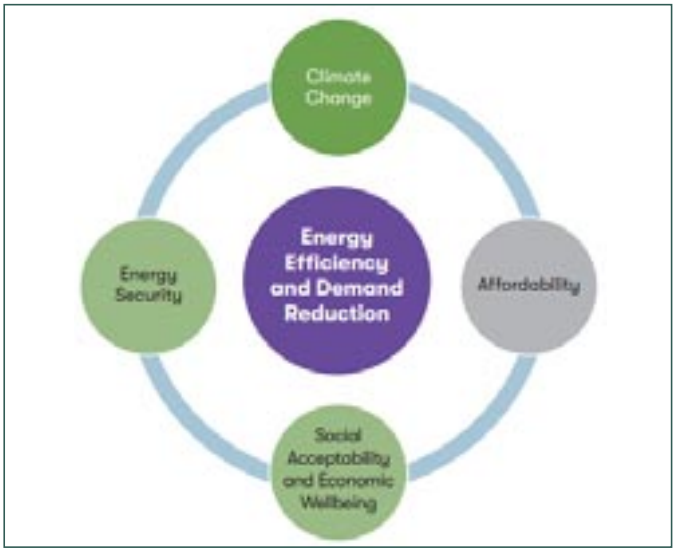
Whether the option is a generation technology, a new kind of storage, a change in public behaviour, or a regulatory reform, none of the choices the Committee assessed provided a silver bullet to solve the 'energy quadrilemma' of reducing carbon emissions, ensuring affordability, providing energy security, and doing all this in a way that is socially acceptable and economically sustainable.

While the report's analysis of the merits and demerits of the options available came to one overarching conclusion – namely, that there are no easy answers – some options did present considerably more advantages



than others. Improving energy efficiency and reducing demand, for example, came out strongly under the traffic light system the Inquiry Committee utilised to highlight the advantages and drawbacks of the options. While a need for substantial investment and the obstacle of Scotland's ageing housing stock were highlighted as issues, improving efficiency and reducing demand was viewed as being imperative to meeting energy goals, reducing emissions and improving energy security.

Other options, such as continued importation, fared significantly less well. While the continued importation of fossil fuels scored well in terms of affordability, due to access to world markets, the fact that Scotland would not fully be taking responsibility for the impacts of production and use, the carbon footprint of transporting the fuel, and an acceptance that the continued burning of fossil fuels exacerbates the problem of climate change were all highlighted as significant drawbacks.



The report stressed that, irrespective of what path is followed, policy makers will have to be up front, direct and honest with the public about the fact that trade-offs are unavoidable. It is then up to our elected representatives to communicate why these trade-offs are being made and attempt to bring the public along with the decisions that have been made.

While the task ahead is undoubtedly incredibly challenging, the hard choices that must be made cannot be kicked into the long grass. With the closure of Scotland's fossil fuel plants in recent years, and planned closures of the two remaining nuclear stations over the coming decade, choices will need to be made on how to generate the electricity previously produced from these technologies. As mentioned, the fall-back choice of simply importing a greater proportion of our energy has serious implications and should not be adopted without serious consideration of these.

It is imperative that, whatever decision is made, the process in reaching this choice is grounded in robust scientific evidence and honest debate over the consequences. Indeed, the ramifications of doing nothing and allowing potential opportunities to slip away could prove far higher and wider-reaching.

The report makes ten recommendations including the need:

• To establish an expert advisory commission on energy to help advise decision makers on all aspects of energy policy and governance;

• For considered and timely investment into options to meet Scotland's energy needs;

• To reduce overall demand for energy and improved energy efficiency measures;

• For a clearly articulated position on security of supply and the need for an increase in domestic generating capacity;

• For serious consideration on how best to socialise the costs of transition to address issues of social justice;

• For all levels of government to review and change existing policies where these are at odds from the overall goal of carbon reduction.

Fortunately, despite the difficult decisions that must be made, the report concluded that there are genuine reasons for optimism. The challenges Scotland, and the world, faces regarding energy should not only be seen as a threat, but also viewed as an enormous opportunity; and one which Scotland must grasp. Some of the options available for meeting future energy needs may prove more financially costly than 'business as usual', but this investment is also a real contribution towards the country's prosperity and wellbeing and could position Scotland as a global innovator.

POST PUBLICATION WORK

Since *Scotland's Energy Future* was published in the summer, work has continued to highlight the report's findings and continue the important debate on energy. In October the RSE held its first policy event at a political party conference, hosting a panel discussion on the report's findings with Scottish Government Minister for Energy, Connectivity and the Islands, Paul Wheelhouse, and Chaired by former Scottish Parliament Presiding Officer Sir George Reid.

In December 2019, the Scottish Parliament's Economy, Energy and Fair Work Committee took up the RSE report as the starting point for its own inquiry into energy, with a particular focus on electric vehicles and smart energy. The RSE was pleased to send RSE Inquiry Deputy Chair Prof Becky Lunn, along with Prof Gareth Harrison, Prof John Underhill and Prof Gavin Little to Holyrood to brief the MSPs on the Committee on the report's main recommendations and findings.

As we enter 2020, the RSE will continue to encourage and facilitate informed, evidence-led debate on energy policy and the decisions that will need to be made to ensure that Scotland's Energy Future is a bright one for all the people of Scotland.

CAN OBESITY GASTRIC SURGERY CURE DIABETES?

Ali Alhamdani Consultant General Surgeon

Diabetes is the epidemic of the century. Type 2 diabetes is related to obesity and cases in the UK and worldwide have quadrupled over the past 30 years. In the UK alone, more than 2 million people are affected with more than 10% of UK health spending being directed to diabetes treatment. This increase in type 2 diabetes is mainly related to the obesity pandemic. Currently there is no specific cure for type 2 diabetes, just management techniques. Unfortunately, for many patients, within a few years of being diabetic, they develop life threatening complications such as heart attacks, strokes, hypertension, peripheral vascular disease, blindness and kidney failure. Hence, finding a better solution for type 2 diabetes is important.

Mr Ali Alhamdani, a senior bariatric surgeon and leader in revolutionising the way we treat diabetes with surgery, explains how we can rethink the treatment of this disease.

HOW CAN SURGERY HELP CURE TYPE TWO DIABETES?

There was a report in the Lancet in 1925 which suggested that a side effect of an operation to treat peptic ulcer disease (an early version of what we now call a gastric bypass) was the remission of diabetes in diabetic patients. They found this by testing glucose levels in their urine, which was one of the early ways to diagnose diabetes. This observation was seen more frequently in the 1980s and in 1990 when obesity surgery was offered to obese patient with diabetes.

Gastric bypass surgery is essentially the last resort to treat obese patients. This operation consists of dividing the stomach into two parts – the small, top part and the remaining lower, large part – and then connecting the top part of the stomach to the small bowel after bypassing 1-2 meters of the small bowel. Recent evidence showed that this type of surgery can control or cure diabetes.

An increasing amount of evidence from the literature now favours the effect of surgery on type 2 diabetes in comparison to other modalities of treatment like medications, diet and exercise. Evidence shows that obesity surgery attacks the symptoms, in addition to the cause of diabetes. Diabetic patients after surgery have their blood sugar normalised within just a few months. They also have less chance of developing diabetic complications like blindness and heart disease. Surgery also helps to reduce high blood pressure and lower high cholesterol levels.

WHY DOES SURGERY HAVE THIS EFFECT?

The exact mechanism of why diabetes is controlled after obesity surgery if not fully understood. A few theories suggest that after the gastric bypass, when food reaches the lining of the small bowel, increasing amounts of gut hormones are excreted which results in increased production of insulin and hence the control

of diabetes. Medical insulin after obesity surgery is stopped on day one, even before the patient starts to lose weight, because of the strong hormonal effect of surgery to control this chronic condition.

A more recent studies showed that this hormonal effect is a result of increase bile acids concentrations in the blood after gastric bypass surgery which stimulates the secretions of those hormones. Bile acids increased concentration in the blood after the operation further helps to decrease the insulin resistance by increasing complex fat synthesis and decreasing the production of glucose in the liver.

The same operation also hits another pathway by affecting the microbiota of the gastro intestinal tract having more

favourable microbiota after surgery that facilitate the absorption of bile acids and hence its higher concentration in the blood after the operations.

In general, gastric bypass works in the obese body by multi-hit hypotheses.

WHAT ARE THE BENEFITS OF TREATING DIABETES WITH SURGERY?

Other than the health benefits and diabetes remission for patients, studies have shown the economical benefits. It is suggested that the cost of the surgery, which is around £10,000-£12,000, will be gained after 2-3 years due to the reduced spending on diabetic medical treatment.

The UK National Bariatric Surgery Registry (NBSR), which conducts a continuous auditing process of the result of obesity surgery in the UK, showed that diabetic people who received surgery had a 75-80% chance of diabetes remission. In addition, the National Institute of Health and Clinical Excellence in UK (NICE) has recently approved obesity surgery to treat diabetic patients with a BMI of 30 and above.

ARE THERE ANY SETBACKS FOR THIS NEW TREATMENT?

There are a few obstacles in view of providing surgery to treat diabetes on a nation-wide scale. One of those obstacles is the high cost of the surgery, however, as already stated this has been shown to be made back in due course. The second obstacle is the prejudice the community has for obese patients, with many holding the belief that these patients bring poor health onto themselves by not following a healthy diet.

I believe it is a time to think differently about diabetes. Type 2 diabetes is a disease that is related to obesity and can be cured, or at least controlled with surgery. When patients know that this is a curable disease, with the last option being surgery, then that might give hope to patients, making them more determined to try the treatment ladder from the start of medical treatment and lifestyle changes and up to surgery if required. Changing the perception of diabetes from a picture of an untreatable disease to a problem that can be solved by surgery is difficult to imagine but as Albert Einstein said once "imagination is more important than knowledge".

"WHY THIS IS THE BEST WEIGHT LOSS SURGERY FOR YOU – WHAT I WOULD CHOOSE FOR YOU AS YOUR OBESITY SURGEON"

Ali Alhamdani Consultant General Surgeon

There are many different factors which must be considered when deciding on the right path to follow for weight loss surgery. Senior bariatric surgeon Mr Ali Alhamdani explains how he decides the best course of action and procedure for the patient.

HOW YOUR OBESITY SURGEON HELPS YOU TO MAKE THE RIGHT CHOICE

Consider patient eating habits

Patients eat differently: they are either large volume eaters, sweet eaters or combination of both. Knowing this is paramount in the decision-making process since each bariatric operation has its limitations with regards to its ability to induce weight loss. For example, sleeve gastrectomy and gastric band are restrictive operations - their impact on soft and sweet food is limited and therefore we could not expect significant weight loss if a 'sweet eating person' is offered a sleeve gastrectomy.

Another example: gastric bypass or mini gastric bypass could cause dumping syndrome for sweet eaters *(when sugar moves to the small bowel from the stomach too quickly, causing cramps and diarrhoea)*, therefore patient knowledge and understanding of their diet habits would help in their recovery. Although this is often mentioned as one of the side effects of this procedure, I believe it is an advantage: it will force the sweet eating patient to switch to the healthy Mediterranean type of

food. This dumping syndrome occurs in 40% of gastric bypass patients.

ASSESS THE MEDICAL HISTORY OF THE PATIENT

Past medical history affects the choice of the operation. For example, patients with severe gastroesophageal reflux and hiatus hernia should not have an operation that exerts high pressure on an already weakened gastroesophageal junction. Sleeve gastrectomy transfers the low-pressure volume stomach sack into a high-pressure system stomach tube. This will encourage the reflux of acid in the already damaged gastroesophageal sphincter mechanism in a patient with gastroesophageal reflux.

Another example illustrating medical history - patients with inflammatory bowel disease like Crohn's or ulcerative colitis should not be offered obesity surgery that might affect the disease process or interfere with the treatment options. Therefore, I would not offer gastric bypass or mini gastric bypass to such patients.

KEEP THE PATIENT'S THOUGHTS AND BELIEFS IN MIND

Some of my patients come and ask specifically for only one operation. I will support offering the patient their choice as long as it will not cause them any harm. For example, some patients would like only the gastric band - and nothing but the band. They believe it is a very safe operation.

This is one of the misconceptions patients have. Problems with the gastric band will not happen in the initial years after the operation. The longer the patient lives with the band the more chance there is of having complications like band erosions and slippages. Some of those complications are life-threatening. One way around this could be to offer a gastric sleeve/bypass or mini bypass, as if a complication is to happen with those operations it will happen early. The longer the patient lives with these operations the safer they are.

It is important to me as a surgeon to listen to what patient want, however it is also important for me to point out any possible risks and give my recommendations while taking into account the patient beliefs surrounding surgery.

FOLLOW THE SURGEONS ACT

Some surgeons believe in only one solution for all patients. Those surgeons believe, for example, in offering only gastric sleeve to all patients, and some believe in offering a gastric bypass to all patients.

I believe that the surgeon should take all the factors above into consideration and only decide after discussing it with the patients and involving them in the decision-making process. This ensures we choose the best course of surgical treatment for the patient.

HOW AI WILL TRANSFORM HEALTH: AND HOW IT WON'T

John Loder
Investment Director, Nesta Impact Investment

John has a particular interest in the potential of data to improve healthcare, and leads Nesta's digital health work, such as Dementia Citizens. He co-wrote Doctor Know, looking at the potential for new ways of creating and using knowledge in healthcare. John also works across other Health Lab projects, such as Helping in Hospitals.

"I never predict anything and I never will" - Paul Gascoigne

Artificial Intelligence (AI) will be a transformative technology over the next few decades, and health looks like one of the areas where it has the most potential. Getting policy and regulation right is vital to maximise its enormous benefits while minimising the substantial risks. And to do this well we need a rough forecast about exactly how AI might be used.

Any attempt at prediction carries the risk of making a fool of oneself, and it is generally a good idea to follow the sage example of Paul Gascoigne above. This is especially true when it comes to AI, a technology that has been through huge peaks and troughs in expectations. However, the task cannot be avoided if we are to be properly prepared.

So in this article I'll take the risk of looking like a fool a few years down the line and offer some tentative suggestions as to what most *transformative* effects of AI that might be in health in the next 10 years - not the biggest technical breakthroughs, but the biggest changes in our experience. This draws on our report Confronting Dr Robot

Press coverage is, I think, a poor guide here. AI tends to get the most attention when it seems to achieve human level performance in some area - like playing go, or driving a car, or diagnosing cancer from a medical image. While this is hugely technically impressive, it is not a great guide to uptake. New innovations generally takes root where the existing approach works *least* well, rather than where it works best. Being better than doctors is a high bar, especially when their full range of skills is considered: spotting problems that are unrelated to the original diagnosis, helping the patient make complex trade-offs, considering psycho-social as well as medical factors etc. Healthcare is at its best when a clinician talks with a patient, and looks at their data - it is the other 99% of the time that most of the problems happen. These areas also tend to have fewer institutional and regulatory barriers to uptake.

So let us look at some of the key moments and decisions that have to be taken outside of the conversation with the appropriate clinician, and where AI can help.

THE INITIAL DECISION TO SEE MEDICAL HELP

We've all indulged in some frantic googling to try and work out if we need to take time off work to see a doctor - and we are not very good at it. Around 20% of people appearing GP surgeries do not need to be there. Similarly there are a large number of people who should be getting their health problems attended to, but don't, often causing problems later.

There are a number of AI powered chatbots in the market which aim to help patients at this point, such as within Babylon's GP at Hand product, which are already being used by thousands of people. Evidence of their efficacy in far from solid - but that hasn't stopped their widespread availability and use.

REFERRAL

GPs do amazing work, but are generalists. When confronted with an uncommon problem, they do not find it easy to know when to refer to a consultant. Referral rates vary between two and twenty times between various GP practices, far more than can be explained by different patient characteristics.

We are seeing the emergence of AI driven referral engines. For example, Google Deepmind and Moorfields Eye Hospital recently published a study showing that AI can make a very accurate referral decision for over 50 eye conditions. C the Signs is live in the NHS today, helping GPs diagnose cancer and make the appropriate referral.

REMOTE MONITORING

One of the most remarkable studies on digital health shows that remote digital symptom monitoring for cancer patients improved survival by 8 months, far more than the average new cancer drug. Ensuring clinicians and patients can react to changes in health quickly can have huge benefits, and AI can play a significant role here. Examples such as Current Health are live in the NHS at the moment, using a mixture of wearable sensors, patient data entry, and AI analytics to monitor conditions in real time, and take action.

Apart from the efficiency and quality impacts mentioned above, AI could also shift knowledge and power into the hands of patients. AI can help patients understand what is happening with their health, be better equipped to know when to seek treatment and to know who would be best to give it. This could strengthen their ability to advocate for themselves, and engage them as more active participants in their own healthcare decision making.

"By far, the greatest danger of Artificial Intelligence is that people conclude too early that they understand it." - Eliezer Yudkowsky

So we are already seeing the emergence of AI in a number of powerful positions:

- AI as the front door - strongly influencing whether patients go to seek treatment.
- AI advising on key moments in the patient journey such as referral
- AI analysing data to flag up patients with ongoing issues who need urgent intervention; or who can perhaps be left alone.

This future would put AI becomes influential about who seeks treatment, when they do it, and who they see. In a perfect world these algorithms would be deployed to do exactly what they are good at, with a clear understanding of their limitations, with appropriate processes to pick up mistakes, and clarity about the ultimate responsibility for decision making.

However the history of technology implementation in healthcare should not fill us with confidence. Its not enough that we properly regulate the reliability of the advice that the AI is giving - we also have to think about the clinical and institutional context in which the AI is applied. In the worst case, it is easy to draw an analogy with the replacement of bank managers by credit scoring algorithms.

- The reasoning behind decisions such as refusing a referral becomes more obscure
- The conversation that would allow a clear picture of the whole patient to emerge does not happen, as feeding data to the AI dominates.
- Even where there are obvious special factors, it is hard to overturn the judgement of the algorithm. The ability of people to interrogate the process, appeal, and advocate for themselves is diminished.
- Those with atypical situations or symptoms, find it harder to progress and advocate for themselves, leading to widening health inequality

All this can happen to a significant extent without AI being given explicit authority to overrule anyone; the mere fact that people are being measured against a standard is a powerful influence, and there will be a temptation over time to include the AI's output in system management and planning discussions, making it substantially influential.

In order to get to the better of these futures a number of principles need to be in place:

CONTROL

AI should give citizens a clearer and more timely understanding of their health and what should be done, in ways that support greater citizen confidence and control.

SIMPLICITY

Well implemented AI should make it quicker and easier for patients to get a resolution to their problem. This requires clarity about the types of problem AI can deal with, and well defined boundaries beyond which human input is required, to avoid AI becoming an additional barrier.

DIALOGUE

The conversation between doctor and patient should remain central. AI should support conversations - ensuring that they are with the right people, that it happens at the right time, and providing the information that supports it. AI should not degrade conversations by over-standardising or taking up unnecessary time.

EQUITY

AI should not be used in ways that exacerbate health inequalities. AI should help all citizens, and most particularly those who face the most challenges and disadvantage in relation to their health and well-being.

ACCOUNTABILITY

It must be possible for AI to be understood, questioned and held to account, otherwise AI could fundamentally disempower users - both citizens and health professionals. Without accountability (and the transparency underpinning it), the rest of these AI principles are hard to achieve - control , simplicity, dialogue and equity all require AI that can be understood and held to account by its users.

I remain optimistic about AI and health, but there is a real need to focus the debate on how its less glamorous but most probably applications might work in real systems and to consider increasing autonomy and dialogue as objectives alongside more technical measures of AI's reliability. Healthcare tech has often been implemented from a system management perspective, and without fully taking advantage of the opportunity to directly empower patients - a set of problems we continue to try to address at Nesta through for example our Healthier Lives Data Fund, in partnership with the Scottish Government.

GEOLOGICAL SKILLS AND KNOWLEDGE CRUCIAL IN DELIVERING NET-ZERO

Professor Mike Stephenson
Executive Chief Scientist (Decarbonisation), British Geological Survey

Florence Bullough
Head of Policy and Engagement, The Geological Society of London

The UK is well placed to research and develop geological solutions to climate change due to the excellent and well-developed knowledge base, mature understanding of the UK's subsurface, as well as world-class universities and research centres.

The geology of the UK - and the geoscientists that have studied it - have played a vital role in the development of the UK's economy. One of the main components of the industrial revolution was the abundance of easily accessible high-calorific coal in parts of England, Wales and Scotland - and the co-location of materials like iron-ore, limestone and coal allowed large-scale construction for the industrial revolution, such as the famous Iron Bridge in Shropshire. More recently since the 1960s offshore oil and gas has brought huge economic benefits and revenue for private industry and UK Government. Around 42 billion barrels of oil equivalent have been produced from the UK offshore so far, each year bringing around £5 billion in tax revenue, and supporting around 450000 jobs. [1]

These developments are related to coal and hydrocarbons – what we could call a process of 'carbonisation' of the economy - but geology and geoscientists will have a powerful and critical role in the 'decarbonisation' of the economy and in delivering the UK Government's commitment to 'net zero' by 2050.[2] Reports from the IPCC [3], the Committee on Climate Change [4] and the Science and Technology [5] and BEIS [6] parliamentary select committees all outline the critical role that carbon capture, utilisation and storage (CCUS) will play in delivering net zero for the UK economy through decarbonisation of industry and power. The decarbonisation of domestic heating and air conditioning across the world is likely to need geothermal energy and a hydrogen economy will need large-scale geological storage.

Ironbridge *(Source – Keith Havercroft, Geograph.org)*

DECARBONISATION TECHNOLOGIES

Three key geologically-related technologies will be needed for decarbonisation: CCUS, hydrogen as fuel and geothermal energy. The UK is well-placed to develop and deliver these technologies due to its favourable geology. The North Sea has the potential to be a major resource for a future CCUS industry, due to the concentration of highly skilled professionals and significant data and understanding that already exists about the subsurface in the North Sea. In the area of geothermal energy, there has been significant activity in the UK, primarily in Cornwall and Glasgow. In Cornwall, investigative drilling at the United Downs site is ongoing, aimed at developing a deep geothermal energy resource in Cornwall, with the potential for a further 20 sites. The British Geological Survey, as part of NERC-UKRI, is also investigating the potential for low temperature geothermal energy at their field site at the abandoned mine workings in East Glasgow as part of the UK Geo-energy Observatories project [7] (UKGEOS). As described below, there are also a

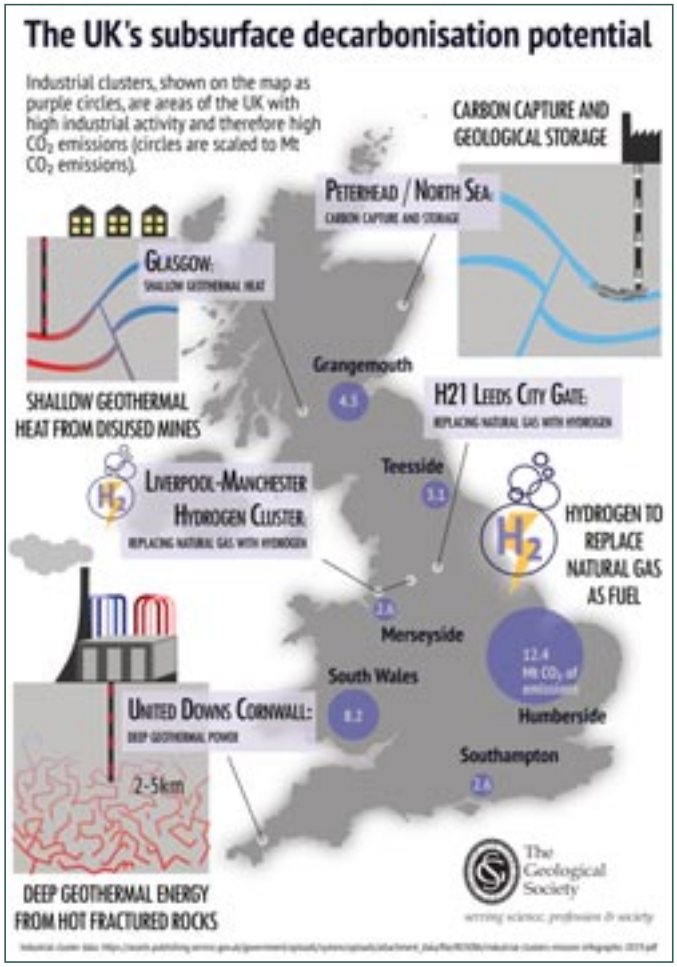


Figure 1 – The UK's subsurface decarbonisation potential *(Image source – The Geological Society)* – Several areas of the UK where there are large industrial clusters, also have significant decarbonisation potential.

number of hydrogen projects in development around the UK. See Figure 1.

LINK TO UK REGIONAL DEVELOPMENT

The nature of geological resources and materials is such that their use in decarbonisation will tend to be place-based. For example, the development of a regional 'hydrogen economy' – where hydrogen provides fuel for vehicles, heating houses and powering industry. Hydrogen's mass production in the short term will be by steam methane reforming (SMR), from natural gas which produces CO_2 and hydrogen. The hydrogen is a zero-carbon fuel, but the CO_2 will have to be used, or disposed of geologically. The key point here is that geological disposal of CO_2 cannot be done everywhere, because only specific geologies are suitable. Critically, there are many suitable locations with supporting infrastructure in the North Sea. It is also known that to make the hydrogen economy work, huge amounts of the gas will be needed, and therefore so will large local storage in the subsurface. In most cases, this means geological storage in underground salt layers.

A practical example is the 'H21' Leeds City Gate project which will convert the existing natural gas network in Leeds – used mainly for heat – to 100% hydrogen. Decarbonisation of heat is a major challenge for the UK, where fossil fuels dominate the sector, see Figure 2. In the H21 project, SMR plants on Teesside will produce the hydrogen and the waste CO_2 will be disposed of offshore in the rocks under the southern North Sea. Subsurface salt cavern storage in the Tees and York areas will be needed for 'intra-day' and 'intra-seasonal' swings in demand as heating is turned on and off by consumers.

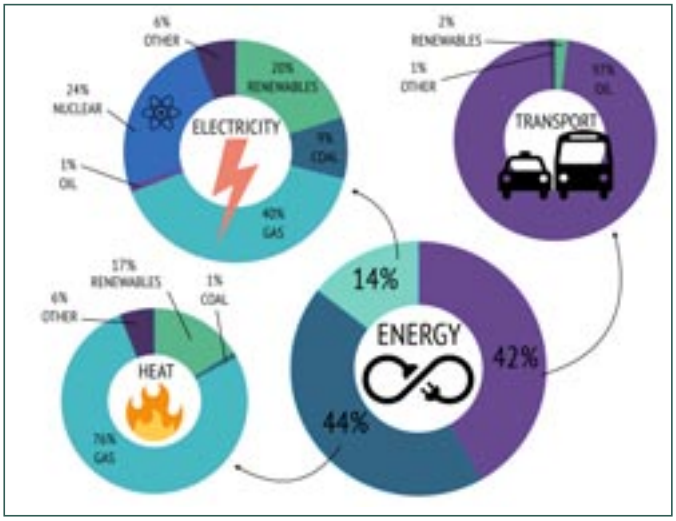


Figure 2 – UK energy demand and supply by sector *(Image source – The Geological Society).*

The Liverpool-Manchester Hydrogen Cluster will decarbonise domestic heat, but also major industrial gas users in the oil refining, glass manufacturing, food and drink, chemicals and pulp and paper sectors. The Liverpool-Manchester area also has suitable geology: the gas fields located in the East Irish Sea off the coast of Merseyside, could be repurposed to provide CO_2 storage; the area is rich in salt deposits suitable for the storage needed for the roll out of hydrogen.

There is also potential for geothermal energy to play a significant role in decarbonising heating in the UK with the added potential for electricity generation. Low temperature geothermal energy in particular, typically groundwater with a temperature less than 20°C, can play a part in decarbonising heating. Huge volumes of such waters exist under the UK's towns and cities. Former industrial areas where waters move very freely because of old coal mine workings may be

Hydrogen-powered bus (© Mike Stephenson) - For a hydrogen economy, for example for use in hydrogen powered-buses, we will need to be able to store large amounts of hydrogen in salt layers.

particularly well suited to domestic heating using below-ground energy. Coal mine heat is being tested right now at the NERC-UKRI British Geological Survey test site, UKGEOS, in the former coal mining area in the east end of Glasgow. Other industrial towns based on or near coalfields, often with fuel poverty, could also benefit from coal mine heat.

Drilling an observatory in Glasgow to study heat in flooded mineworkings. © *Mike Stephenson.*

The research and development associated with CCUS, geothermal and hydrogen will develop in geographical clusters around the UK that can exploit existing industrial infrastructure as well as natural geological resources and other advantages to allow local solutions. These regional hubs will concentrate skills and investment, as previously in the development of North Sea oil and gas off the coast of Aberdeen. Development of regional energy projects such as these will also be important for delivering the UK Government's support of 'strength in place' and regional development policies set out in the Industrial Strategy[8]. Across the UK, local 'energy ecologies' – collections of energy users and producers - are beginning to work together to decarbonise. The local funding arrangements of the Government's new Industrial Strategy will target government funding along with co-funding from industry to address market failure. The cluster concept underlines the need for industry and government to work together to decarbonise, but also the importance of the distribution of useful rock types, and ultimately the importance of geoscience knowledge and skills in decarbonisation [9].

The solution to net-zero will not be a 'silver bullet' technology but a variety of solutions, both national and local. Incorporation of geological solutions into local industrial strategies and investment in geological skills will be critical to meeting the decarbonisation challenge and stimulating economic growth across the UK.

HOW CAN PARLIAMENTARIANS HELP…

- Appraise and build geological solutions to climate change into local industrial strategies. For example, where there is the potential for geothermal energy in a given area, ensure that the requisite licensing regulation is developed to support technological development.
- Promote the important role of geological skills and the UK's local geology in the development of decarbonisation technologies, both regionally and nationally, particularly when developing national policy around investment in research and development and workforce training.
- Strengthen the geoscience skills pipeline through investment in the UK's outstanding universities sector and support the development of immigration policies that allow for the movement of international researchers and students.

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ENGINEERING THE FUTURE OF THE UK

Professor Colin Turner PhD FIET FIMA PFHEA NTF
President, Engineering Professors' Council
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The Engineering Professors Council (EPC) represents the academic engineers in the UK, with 85 university engineering faculties as members comprising over 7,500 academic staff.

Our primary purpose is to provide an influential voice and authoritative conduit through which engineering departments' interests can be represented to key audiences such as funders, influencers, employers, professional bodies and Government. All branches of engineering are represented within the EPC's membership.

It's well understood that the UK needs to upskill its population to stay competitive in a world economy, as well as to meet other domestic needs.[1] The engineering sector is vital to the UK's economy, generating more than £1 in every £5 of UK turnover, employing 5.6 million people and producing the majority of UK exports.[2]

However, there are challenges. The current and projected annual demand is that the UK will need 59,000 more engineering graduates and technicians than we currently produce. The engineering profession also suffers from a stark gender imbalance: only 12% of engineers/technicians in industry are women who comprise 47% of the UK workforce. A similar issue affects BME engineers: 8% of engineers/technicians are BME, while BME workers form 12% of the UK workforce.

These two problems of shortfall and lack of diversity have the potential to at least somewhat offset each other. Just as importantly, UK Engineering would benefit substantially from greater diversity in its outlook.

Substantial effort and attention is being committed to these issues and progress is being made in many areas, but it is still too slow – and there is increasing awareness of the important role engineering must play in modern challenges, like climate change, and caring for an aging population.

ENGINEERING IDENTITY

Engineering suffers from an image problem. Most people are unaware of the part that engineering plays in their life in the same way that whales probably give little thought to the importance of water. The products of engineering are everywhere: the computer on which I am typing this, the seat on which I am sitting, the clothes I am wearing, the tiles under my feet, the building materials and infrastructure where I am, the roads and paths by which I travelled here.

Compounding this, engineering's greatest accomplishments are often attributed to science alone. While the Saturn V rocket that took humans to the Moon was a product of engineering, the popular term is "rocket science" and not "rocket engineering", the profession didn't even get much credit for the fact that the first two humans on the Moon were engineers – which was not a coincidence. Not for nothing is the word "engineer" descended from the same Latin stem as "ingenuity".

The contribution that engineering has made to quality of life and enhanced lifespan is also due to its direct intervention in healthcare. It takes only a small perspective change when in a hospital to become aware of just how much of the equipment and medicine that is being used and surrounds patients has been produced by engineers. This is true outside clinical settings too, for instance mobile defibrillators (first developed in Northern Ireland) can now be found in corner shops, carefully engineered to be used by untrained people.

Despite this, it is entirely possible for our most scientifically literate school students to have little or no knowledge of what engineering is, or worse, to have significant misconceptions. I can personally attest to this; my degrees are not in engineering – I am an immigrant into a profession that requires and absorbs expertise of all sorts. Fewer than a quarter of young people aged 11 to 14 reported knowing what engineers do. At this age they can already make subject choices that will make entering the engineering profession later more difficult.

Many tend to have an image of engineering that it is low-paid, low-skilled work, involving heavy labour, when none of this is true. Some of this may directly contribute to the gender issue, but some newer areas may be freer of stereotypes – the proportion of women studying biomedical engineering far exceeds that for mechanical engineering and electronic engineering.

Some notable campaigns are helping. "Primary Engineer" – introducing primary school students to engineering and asking them what they would invent. "This is Engineering" – a campaign led by the Royal Academy of Engineering also

seeks to overturn misconceptions and increase diversity in the profession – their videos have had over 37 million views. The Year of Engineering in 2018 – championed by Stephen Metcalfe MP have all helped to raise and change awareness. This momentum must be maintained and increased.

SUSTAINABILITY AND ETHICS

Another important shift in the engineering landscape is a dramatically increased focus on the issues of sustainability and ethics. These have long been a mandatory part of engineering courses accredited by the Engineering Council, but it's fair to say that the prominence of these ideas has risen sharply.

It's been sometime since Professor Raffaella Ocone first suggested that there should be some analogue of the Hippocratic Oath for engineers – certainly the work of many engineers has life or death consequences, just as in medicine. The importance of engineering ethics has probably never seen so much attention from the variously involved professional bodies. It is the subject of academic conferences, joint work by the Engineering Council and the Royal Academy of Engineering, and indeed the Engineering Professors' Council Board has dedicated a strategic retreat to it.

Issues such as the Climate Crisis have underlined this need. The widely held opinion that the climate change is anthropogenic – and essentially driven by our technical evolution since the industrial revolution places a particular onus on engineers. Even if one takes the contrary view as to the origin of climate change, its effects still require major efforts of engineering to ameliorate. It will be engineers who produce technologies that affect CO_2 levels in our atmosphere and oceans, but it will also be engineers who will lead the effort in protecting our populations against the existing impacts and create a sustainable future.

POLICY IMPERATIVES

The UK needs to grow its world class engineering industry, driving innovation and our export economy. To do this, as engineer Nick Cooper puts it succinctly "we need more engineers and we need more people that think like engineers". We must address the diversity issues in engineering and ensure that more people are aware of what engineering is, what it does for them and what it might offer them as a career.

Engineering education must embrace many challenges: an ever-increasing depth and breadth of scientific and mathematical background as new science is developed; the need to develop the soft skills which are just as important in industry; and a much greater focus on issues that have historically sometimes been paid lip-service – such as ethics and security.

The UK needs a mix of engineers with varied backgrounds and specialisations, both within certain discipline areas, but also to have a mix of those engineers with elite academic skills and those with more industrial focus. This can be achieved by diversity of engineering degrees and FE awards, and by effective degree apprenticeships. Degree apprenticeships are perhaps off to a shaky start, and the EPC is working with stakeholders to help ensure their success.[3]

There are signs that not all degree courses are ideally suited to students from all academic backgrounds, and this might be expected, but it is important to consider that in some geographical areas of the UK, students at 18 may have very different (and in some cases limited) access to traditional A level academic backgrounds in subjects like Maths and Physics. As a sector, there is a need to consider more explicitly who has access to A levels, T levels, BTECs and apprenticeships. While some "conversion courses" offering degrees in engineering to other graduates exist, more of these are necessary.

The educational pipeline for engineers, and the success of UK engineering to industry is dependent on the UK's cutting-edge science and engineering research track record. The commitment to increasing to a 2.4% spend of GDP on R&D is an important part of this, but it's equally important to look at how some policies can produce multipliers on cash spend. For instance, the EPC's own research[4] estimates that access to the Horizon 2020 programme has multiplied the effect of EU-research income by 3.35. In a post-Brexit UK, it will be important to consider the net benefit we may have in access to such schemes in the future. Similar arguments can be made for the benefits of Erasmus+ which has aided student and staff mobility within the EU up to now.

Our future needs ingenious people to build it and safeguard it. We have those people, but we need more of them and we need them to come from all parts of our society.

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VISIT OF DELEGATION FROM GANSU PROVINCE, CHINA

Professor Ian Haines
Executive Secretary UK Deans of Science
Emeritus Professor London Metropolitan University

With colleagues at London Metropolitan University, Ian Haines established undergraduate and research collaborations with Shanghai University of Traditional Chinese Medicine which lead to the creation of a joint research facility on its new campus. He developed a longstanding joint undergraduate programme in computing with the Hong Kong Computer Institute (now the International Academy of Management).

As part of its intention to extend its international reach the Parliamentary and Scientific Committee met with a delegation from Gansu, China on 16 October 2019. The delegation included the Chen Bingdong, First Vice-President, Gansu Association for Science and Technology, Ma Zhongming, President of Gansu Academy of Agricultural Sciences and colleagues involved in agricultural science, environmental science, water conservation and forestry and international liaison as well as representation from Lanzhou University (with an interest in smart intelligent systems) and the Chinese Embassy. The meeting was hosted in Committee Room 14, in the Palace of Westminster, by Stephen Metcalfe MP, Chair of the Parliamentary & Scientific Committee and members of the P&SC Council.

Gansu Province is located in north-central China. It is a predominantly agricultural region but has a significant mining industry that includes a range of rare earth elements. Amongst several challenges it needs to develop forestry to protect soil and prevent soil erosion. The purpose of the visit was to engage with P&SC to discuss potential academic and other collaboration and exchange between Gansu and the UK.

The discussions evolved around three priority areas for collaboration and potential scientist exchanges :

- the need to increase agricultural productivity, including issues of water use and crop development for higher quality, greater yields, drought- and pest-resistance
- potential changes to future crops needing to be cultivated to account for climate change and the need for innovation in the development of 'green agriculture'. The delegation emphasised that they regarded climate change as a global challenge and not one limited to Gansu or China
- development of intelligent agriculture, integrating AI and related technology to control the planting, cultivation and harvesting of crops.

It was agreed that as a follow up to the meeting P&SC would send further information on some UK organisations involved in aspects of agricultural science and associated technologies and funding opportunities for collaboration, between China and the UK.

Within a few weeks of the meeting the first opportunity arose to deliver on the agreement by sending

information on the Innovate UK competition for UK-China collaboration on 'Precision for enhancing agricultural productivity' (https://apply-for-innovation-funding.service.gov.uk/competition/482/overview). The UK and Chinese Governments have agreed to each contribute £5million to support this initiative. The intentions of the competition are to encourage the use of data-intensive methods for commercial farming. Bids were encouraged in areas such as monitoring, intelligent decision support leading to business-led outcomes in one or both of the autonomous technologies (sensors, systems, vehicles and robotics) and data-driven solutions to enhance productivity while reducing emissions.

ANDREW MILLER 1949-2019

Science has lost a great Parliamentary friend with the untimely death of the former Chair of the Parliamentary & Scientific Committee Andrew Miller who died on Christmas Eve 2019. He was 70.

A tribute from Dr Stephen Benn, Vice President

Andrew was involved in science ever since 1992 as MP for Ellesmere Port & Neston to which he was re-elected five times. His previous experience as an official in the Manufacturing, Science and Finance [MSF] trade union brought with it a predisposition to take an interest. He had earned a diploma in industrial relations from the London School of Economics and had worked as a laboratory technician at the then Portsmouth Polytechnic. Andrew had been born in Isleworth, west London and was educated in Malta (about whose politics he was always well informed) and later Hampshire.

Early in his Parliamentary career he took a keen interest in the development of the Parliamentary Office for Science and Technology [POST] and was a member of the Parliamentary Science and Technology Information Foundation which helped bring it into existence.

As with any MP Andrew also found himself involved with constituency issues. As a local MP he became embroiled in 1997 in a very famous and tragic case involving a young British woman who had been the carer of a baby in the USA and whose parents blamed her for the death of their child. He was an assiduous local MP and played a key role in helping to support, and bring closure, to his constituent.

He was active in many other areas too – he chaired the House of Commons Regulatory Reform Committee in the early 2000s and in 2007 he piloted the Private Members' Bill that brought the Agency Workers Directive into UK law – but Andrew was always rightly proud that in 2010 he became the very first *directly-elected* Chair of the House of Commons Science and Technology Select Committee. It gave him an authority unmatched by his predecessors.

He also valued the opportunity that this gave him as a member of the Commons Liaison Committee so that he could (and did) raise science issues directly with the Prime Minister.

He set about making the Select Committee as active as possible and in combination with his Chairship of the P&SC this made Andrew the dominant voice of science in the 2010 Parliament.

There were times when the Select Committee under his guidance had to move very quickly indeed as, for example, when Pfizer gave no notice to Parliament of the closure of their important site in Sandwich. Andrew convened an emergency hearing and the Committee's report discovered that the closure plans had been in the preparation for much longer than officially admitted.

As Chair of the Select Committee he ensured it benefitted from some very capable specialist assistants in the committee office. On one occasion he successfully used their expertise in the production of a very authoritative Select Committee report on rare earth metals.

He also nurtured and encouraged fellow Members with an interest in science and presided over a Select Committee that really made its mark in the 2010 Parliament (and has continued to do so since).

Andrew was a staunch supporter of all the major science events in the House. STEM for BRITAIN was a particular example. He worked tirelessly (as did his office) to make it the foremost example of bringing science research into the House where early career researchers presented their work and explained it to their local MP.

Voice of the Future was another. He once described it as "like no other event on the planet" and led his fellow MPs in answering Questions from young scientists and engineers.

He strongly supported *Parliamentary Links Day* where each year he took the lead in welcoming scientists and Parliamentarians to the House on the biggest single day for science in the Parliamentary calendar.

He presided over the P&SC's 75th Anniversary in 2014 and welcomed the then Prime Minister Rt Hon David Cameron MP to the celebrations held in the House. He was also present at the special celebration held at Buckingham Palace hosted by HRH The Duke of Edinburgh (the longest member of the P&SC to this day).

Andrew was hard working and widely liked and admired throughout and on both sides of the House and was as familiar a face in the tearoom with fellow MPs as he was in the Stranger's Bar with visiting scientists. His bonhomie was infectious and well-intended and as Chair of the P&SC he encouraged many interesting discussions at dinner after the formal meetings had concluded. He was always very proud of his family and sometimes referred to them in oral evidence sessions. He also took the lead in improving links with the science community in the USA.

He *chose* to retire from Parliament and as a result could return to visit it with his head held high – which he did from time to time. Standing down also enabled him to do other things that he had planned to do to help science – sadly not for as long as he had originally hoped.

On the 26 March 2015 – at a Parliamentary Farewell just before he left the House – no less than 20 science organisations gathered together to thank him for all his work on behalf of science.

He returned to the House in 2016 to receive a Lifetime Achievement Award for Outstanding Contribution to the Cause of Science and he was surrounded by all his many friends in the science community.

In the 2010 Parliament Andrew bestrode the House like a scientific colossus for he chaired the two major science committees (S&T Select Committee and P&SC) at one and the same time. He came to regard it as the happiest of the five Parliaments in which he served over 23 years.

He will be greatly missed and will always be remembered.

THE CHALLENGES AND OPPORTUNITIES FOR UK-IRELAND COLLABORATION IN HIGHER EDUCATION AND RESEARCH POST-BREXIT

Professor Gerry McKenna MRIA

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Brexit has presented a number of challenges for the future relationships between the United Kingdom and the Republic of Ireland. The negotiations leading to the EU Withdrawal Agreement were difficult as both the UK and the EU sought to achieve their respective objectives while ensuring the avoidance of a hard border on the island of Ireland and the maintenance of the Good Friday Agreement. Post-Brexit there is an obligation on both the UK and Irish governments to find ways of supporting and reinforcing the natural and historic linkages between these islands for the benefit of the citizens of both nations. Nowhere is this more important, or more likely to yield synergistic results, than in the field of higher education (HE) and research. There are a wealth of opportunities to build upon and develop further the productive network of North-South and East-West collaborations that already exist within the island of Ireland and between Ireland and the UK. It is to be hoped that the development of this sector will be a strategic priority for the re-established Northern Ireland Executive and Assembly, and North-South Ministerial Council.

Notwithstanding the UK's withdrawal from the EU, there is widespread support among the academic and research community in Northern Ireland (NI) for continued participation in future EU research framework programmes. EU funding schemes, both European Regional Development (Structural) Funds (ERDF) and Research Framework Funds, have been a significant source of funding for research and capacity building across all disciplines. This is particularly true for humanities and social sciences research which has played an essential role in promoting social and cultural development and understanding. It is to be hoped that any future UK funding arrangements should ensure investment across the spectrum of academic disciplines.

OPPORTUNITY AND NEED

There is both opportunity and need for a suite of programmes designed to support increased UK-Ireland collaboration. This includes regional specific initiatives to deal with Northern Ireland's chronic underfunding of higher education (over £2,000 less per student fte relative to England) and the associated cap on student numbers [1].

Science relies on the exchange of ideas and collaboration across borders. This is particularly relevant on the island of Ireland where joint research projects, collaborative degree programmes, cross-border businesses and organisations have grown and flourished within the relatively peaceful environment that has existed in recent years. It is important to reflect on this unique relationship, and to consider what future opportunities and challenges there are for scientific research and development.

High levels of North-South collaboration across all research disciplines are reported by Queen's University Belfast and the University of Ulster. Similarly, Irish universities and institutes of technology report high levels of collaboration with researchers in Northern Ireland, England, Scotland and Wales [2].

- **63% of successful Northern Ireland's projects to the EU's Horizon 2020 research programme involve research partners in the Republic of Ireland [3].**
- **79% of academics in an all-island survey by the Royal Irish Academy agreed that collaborations between Irish and UK higher education institutions are very important in their field of study [4].**

Future UK funding arrangements should enable regional distribution of a significant proportion of research

funding to help build specific North-South research collaborations and support the continued movement of researchers and students in both jurisdictions to access research infrastructure and skills training.

Measures to grow the pool of talented UK researchers should address regional challenges to retention as well as the attraction of international talent, including immigration measures. The proportion of researchers from outside the UK varies by region.

- **43% of Northern Ireland's researchers are from outside the UK - the highest proportion across all UK regions** [5].

The ability to attract international talent is therefore crucial to the future success of Northern Ireland research.

Retention, as well as attraction, of researchers is also a key challenge for the NI research system.

- **One in six of Northern Ireland-born graduates of working age live in England and Wales, with more living in Scotland** [6].
- **Only a third of Northern Ireland graduates who studied in England, Scotland or Wales returned to NI to work in 2017** [7].

There are emerging significant skills gaps across the region which pose challenges for R&D, innovation and industrial competitiveness. The 2018 Northern Ireland Skills Barometer published by the Department of the Economy suggested 87,000 new jobs would be created by 2026, of which around a third are expected to be filled by students and migrant workers. Retention of talent is therefore a key challenge for future research investment strategies for the region.

The delivery of a new framework for research funding across the UK should be informed by a clear understanding of the existing spatial and regional R&D investment baseline figures and a commitment to building regional capacity, addressing skills and enabling innovation. As outlined below, there is considerable disparity in regional investment in R&D with Northern Ireland operating below the UK average at present [8]:

- **While the UK spent £527 on R&D per capita in 2017, there were large differences between the nations. England spent £554 and Scotland £466. Northern Ireland spent £371 which is well below the UK average.**
- **Most of the UK R&D expenditure was carried out in England, at £30.8 billion (89%) in 2017. Scotland accounted for £2.5 billion (7%), while NI spent £744 million (2%) on performing R&D.**
- **The NI Department for the Economy (DfENI) investment in universities' R&D in 2016 was £47million, which is £25 per capita compared to the UK average of £31. The Scottish Funding Council invested £279 million in R&D which is £52 per capita, which is more than double the local per capita investment by DfENI, and well above the UK average.**
- **The level of investment by the Research Councils in NI in 2016 was £32 million which is £17 per capita in comparison to the UK average of £31.**

Conversely, the levels of ERDF funding between 2014-20, which is based on regional disadvantage, were £50.3 per capita in NI as compared to £24.3 for Scotland and £12.6 for England.

INWARD INVESTMENT AND INTERNATIONAL COLLABORATION

Within the UK and Ireland, higher education and research are essential factors in attracting inward investment and are a major contributor to export income through the recruitment of overseas students and international partnerships. At a regional level, universities are also engines of growth by supporting the rebalancing of the economy, by creating local jobs, by encouraging local innovation and by attracting investment and talent. Northern Ireland is particularly dependent upon the economic and social benefits of higher education as it attempts to transform its economy to develop a knowledge-based industrial sector and to encourage Foreign Direct Investment [9].

Beyond whatever agreements and funding arrangements the UK may reach relating to future participation in EU Research Framework programmes, its overall international research strategy should involve opportunities for collaborations with those countries with which it has an existing well-established and impactful scientific research history. As has been highlighted in the Smith and Reid (2019) [10] proposals for future international collaboration on research and innovation, existing bi-lateral relationships such as those that exist between national academies in Ireland and the UK offer an immediate mechanism through which to deliver scaled-up collaborative research funding schemes. Working in partnership with research funding agencies and government departments, the academies offer a well-established high prestige framework through which to support research in all disciplines.

PROPOSALS

The Royal Society and the Royal Irish Academy have jointly agreed a number of recommendations to strengthen research collaboration across the island of Ireland and between Ireland and the UK [11], including:

- **Creating a bespoke suite of programmes including bilateral funding agreements to support North-South, East-West academic research mobility, innovation and skills/talent development and appropriate research infrastructure.**
- **Encouraging support for all-island bodies such as the Royal Irish Academy to create further opportunities for all-island and UK-Ireland dialogue, interchange and collaboration.**
- **Maintaining access to EU structural funding programmes (ERDF, ESF, PEACE and INTERREG) or their replacements and ensuring a strong focus on research and innovation, so that the economy of NI and the Border Region of Ireland can continue to grow and prosper. In the event of such funding no longer being provided through EU structures, it should be provided directly and ring-fenced by the UK government e.g via the Proposed UK Shared Prosperity Fund or equivalent.**
- **Exploring the possibility of developing and enhancing UK-Ireland bilateral research funding schemes with other countries, such as the expansion of the US-Ireland**

Research and Development Programme to extend to additional thematic areas in science and engineering and to include the humanities and social sciences.

- Maintaining close collaboration and providing mechanisms for close cooperation with key European partners to continue the delivery of excellent research in Northern Ireland and the Irish Republic.
- Seeking the continuance of regulatory and standards equivalence with EU countries and promoting the continued recognition of professional qualifications between the UK and the remaining 27 EU member states.
- Promoting increased and coordinated investment in research and innovation, through government initiatives in Northern Ireland and the Irish Republic to support cross-border collaboration and innovation that will drive economic growth.

Specific required actions include:

- The development of joint North-South research centres, academic and research appointments and joint research studentships, to enhance the profile and international impact of HE and research across the island of Ireland.
- The development of regional research-enhancement funding by UK Research and Innovation to expand Northern Ireland's research capability.
- Ring-fencing of the research component of the UK Shared Prosperity Fund and using it strategically to enhance research capability in the Northern Ireland HE sector.
- The development of all-island research-equivalent trade / study missions to build new overseas research capacity collaborations.

The recent proposal to develop a cross-border university based on existing university and institute of technology campuses in the North-West is a potentially innovative development. Such an institution could have significant advantages in terms of accessing both EU and UK research funds. Provided other major infrastructural shortcomings for the region were addressed, a new multi-campus university could provide the knowledge and skills base and platform for a North-West (North Atlantic) Ireland/Northern Ireland economic corridor to offset the infrastructural deficit in that region which has had limited investment from the various governments (Irish and NI/UK) [12].

THE SHARED GOAL?

Brexit imposes a number of challenges for future collaboration in higher education and research between Northern Ireland and the Republic of Ireland and between Ireland and the UK. However, if addressed strategically and innovatively these challenges can lead to synergistic and mutually beneficial economic and cultural outcomes and enhance the historic ties between the British and Irish nations.

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DIFFICULT COMPROMISES ON THE ROUTE TO ZERO CARBON FOR ELECTRICITY AND TRANSPORT

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The world is faced with several problems that are going to have to be addressed by systems engineers and scientists working with politicians. The greatest of these is the urgent need to reduce the carbon emitted by human activities to a level that will prevent unacceptable global warming. This is proving extremely challenging and many difficult compromises will have to be made before we reach zero carbon.

The first is to accept approximations for what is happening. The modelling of how human behaviour is changing weather systems is even more difficult than modelling weather itself, and while there have been great advances in weather forecasting, accurate long-range forecasts are still beyond our capability. The problem must be tackled by what is called chaos theory. Chaos theory is a scientific theory describing erratic behaviour in certain nonlinear dynamical systems. It shows how small perturbations can result ultimately in immense phenomena and has been applied successfully to the modelling of weather. In the case of forecasting, however, many of the data sets needed to tackle the problem are incomplete, or insufficiently precise because of the limited number of sensors that can be placed in the atmosphere. The problem is also so large that precise solutions are beyond the capability of even the largest supercomputers. As a result, engineers and scientists trying to find ways to avoid global warming must work, as is often the case for engineers, where they don't have the data or the techniques to fully understand what they are trying to do. They have no option but to compromise and live with approximations.

In this case the consequences of failing to act rapidly are so dangerous that there is no question of waiting until we really understand this complex problem. Snow and ice cover are clearly decreasing and as they do so the ground absorbs more heat and warming accelerates. Climate scientists have done their best to come up with accurate estimates of the temperature rise that are acceptable and these have to be used as a starting point. Some of the consequences of their predictions have proved optimistic and others pessimistic but in order to get on with it we need to address the worst cases and to act as quickly and strongly as social, financial, and engineering circumstances allow.

The UK has set the target of zero carbon by 2050 that should, if matched by others around the world, allow us to stay below the maximum acceptable temperature increase set by the climate scientists. Some countries have set more aggressive targets but others, including some of the largest, are yet to set any aggressive targets. Overall it has become clear that we need not only to reach the 2050 target but to minimize the total CO_2 in getting there and preferably reduce the emissions as early as possible.

There are many ways of meeting our targets. In this article I am addressing some of the key issues relating to the elimination of carbon from our power stations and our transport systems with a brief mention of heating. I will not be considering alternative fuels for internal combustion engines such as hydrogen although they may well prove valuable in lowering carbon emissions. I will not discuss the removal of carbon by planting trees or adopting the recommendation of the Intergovernmental Panel on Climate Change (IPCC) of conserving and creating areas of peatland, which are the largest

natural terrestrial carbon store and can trap carbon for centuries.

I will also not discuss the contribution of aviation to anthropogenic climate change although the IPCC has estimated that this is 3.5%. Electric powered commercial flight seems far away although there is some hope that hybrid powering of aircraft might be helpful in reducing the carbon per passenger mile, which is estimated to be higher than other forms of transport. Fossil fuels would have to be used for take-off but electric power might be able to contribute during cruising.

Despite all the unknowns there does appear to be general agreement that, ultimately, we should use electricity for most of our energy needs. The major exception is heating, which consumes about 25% of our energy, but even here one might consider using electric heat, but this would be expensive and place huge demands on generation. In the meantime, we will have to rely on heat pumps, improving the insulation of our building stock, wearing warmer clothes and perhaps building more district heating systems that use waste heat from industry and from power stations, especially from nuclear plants.

However, wherever we use electricity it will have to be carbon free before the electrification strategy is effective. This is most obvious in the case of electric vehicles. While electricity is still generated from fossil fuels, and power plants continue to emit CO_2, the use of electric road vehicles will not eliminate carbon. It may be useful in cleaning the air in cities like London, but it only changes the place where the carbon is emitted. It may even be better to compromise and continue to use some of the most efficient combustion engine vehicles while we work towards zero carbon electricity. This is because a large fraction of the energy from fossil fuel power plants is lost before it ever reaches the wheels of electric vehicles.

In most fossil fuel electrical power stations chemical energy stored in natural gas is converted successively into thermal energy, mechanical energy and, finally, electrical energy. About 50% of the energy in the gas emerges as electricity. This electricity then must be distributed over the grid to the user with a further loss of 10% -15%. It is finally converted back into mechanical energy in the vehicles. Ironically, it is more efficient to put the fossil fuel in the vehicle where it can be converted in one step to mechanical energy, even though the most efficient combustion engines only have a thermal energy efficiency of about 40%.

This is especially the case with road vehicles where at present there is no way to deliver the electricity directly to them while they are moving, as it can be with trains. The electricity has first to be stored in a battery and then converted back to mechanical energy. This introduces further energy losses of about 20% in the charging system and the battery. There is also the issue of the carbon produced in manufacturing lithium batteries, which, if fossil fuel derived electricity is used in their manufacture, can be as large as that emitted by a fossil fuel car in its first 70,000 miles.

There is the benefit with electric vehicles that energy can be recovered while braking but this gain is unlikely to make up for the losses incurred in the generation, distribution and storage of electricity. Non-plugin hybrid cars make little or no contribution to reducing carbon as all the energy they use is derived from fossil fuel. However, because drivers of hybrid cars are conscious of the need to conserve energy, they are likely to drive without accelerating hard, and at reasonable speed, and probably produce less carbon than other drivers. This is a good example of how human behaviour is also going to be important in reaching our carbon goals.

In conclusion, despite the reductions in carbon we have made with renewables and nuclear, we will have to go further towards carbon free electricity before we can reach zero carbon with electric vehicles. It is no good looking at vehicles alone. The entire energy system comprising generation, delivery and use, and the manufacture of batteries, must be considered and optimized.

Another difficult compromise in trying to reduce carbon as quickly as possible arose when it was realised a few years ago that nitrous oxides were more dangerous to health than had previously been thought. This realization turned upside down the strategy of European vehicle manufacturers. Their strategy had been to place highest priority on reducing carbon emission and optimizing fuel consumption by switching to diesel engines, rather than on health. Diesel engines are inherently more efficient than conventional petrol engines because of the nature and temperature of their combustion process. Engine manufacturers had eliminated particulates and many polluting gases from diesel exhaust, but more nitrous oxides remain than in the exhaust of petrol engines. The consequence has been that the most efficient and lowest carbon fossil fuel combustion engines are now being outlawed making it even more difficult to reduce the carbon from fossil fuel cars. This emphasizes once again that we must decarbonize electricity generation as rapidly as possible to make electric propulsion zero carbon.

We can eliminate CO_2 in the generation of electricity by using a combination of low carbon intermittent wind and solar sources with constant sources such as nuclear reactors or hydro-electric-power. Alternatively, we can store excess power from renewables so that it can be used, for example, when the wind is not blowing and there is no sunshine. However, this will require storage of hundreds of gigawatt-hours, which can only be approached with immense hydro-electric schemes that are rarely possible. Other means of storage are under development but will struggle to become practicable on the time scale required.

Batteries are going to be useful for short term rapid balancing on the grid but will be too expensive for long term national scale storage. It has been suggested that the batteries in cars could be used to backup renewables, but this would require everyone being prepared to randomly give up use of their cars and leave them connected to the grid. Maybe politicians can persuade people to do this, but it is going to be a challenge.

There is also the possibility of capturing the CO_2 in the power station and sequestering it away under the ground, perhaps using the facilities used now for extracting fuel. It is proposed that this carbon capture and storage (CCS) can be used at national supply levels but attempts to store these massive quantities of CO_2 are yet to be commercially viable. CCS is actively being developed, however, and hopefully will become available in the next

couple of decades and allow us to continue to use fossil fuel powered power stations.

Failing the development of viable CCS, or large-scale storage, the only alternative for backing up renewable generators on a predictable time scale, is nuclear power. Fortunately, this has been realised by recent UK governments, although it is unclear that we are proceeding fast enough to have enough nuclear power in place to meet the 2050 target. Replacing and expanding our nuclear capability appears at first to be another difficult compromise because initially nuclear is going to be expensive. On re-examining this problem, however, it appears that, as with other forms of energy, there are ways of reducing the cost of nuclear.

For example, recent cost comparisons made between renewables and nuclear need reviewing. The present cost of nuclear has been elevated by extremely high borrowing costs (9%). This has led to the extraordinary fact that the financing cost of the Hinkley Point European Pressurized Reactors, EPRs, is well over 50% of their total cost. The high finance cost was evidently justified because no-one had succeeded in building the EPR reactors when the project was started, and people questioned the validity of their design. EPRs were being built in France and Finland but were yet to be completed and were over budget and years late. Regrettably this situation remains. The risk that they might not be successful was therefore relatively high. In the meantime, however, China General Nuclear completed two EPRs in Taishan, about 100 miles west of Hong Kong, and these reactors are each delivering power up to 1.66GW to the grid in China. The technical risk that EPRs might not work has therefore been removed and borrowing costs like those available to investment grade projects, about 4%, should be used for future reactors. It has also been estimated that building replicas of the first systems will further reduce cost. So far in the UK we have never built a replica of a nuclear reactor. Every new reactor has been different.

The opposite situation exists with wind power. It may be that the cost of implementing off-shore wind power is being under-estimated because the high cost of connecting the thousands of wind turbines needed, for example to provide the same power as Hinkley Point, to the grid has not been taken fully into account. This could add 25% to the costs presently used for offshore wind. Another factor is lifetime. The wind energy industry and the Government base their calculations on wind turbines having a lifespan of 20 to 25 years. This is to be compared for example with the case of a new nuclear plant like Sizewell C where it has been said, "it could last for 60 years."

Small and Modular nuclear reactors also offer the opportunity for lower costs and UK governments have been assessing their feasibility for many years. Fortunately, after endless delays, £18 million was committed last July to support a consortium led by Rolls Royce that is proposing to build SMRs with an output of 220 MW - 440 MW. These SMRs can be built with prefabricated components in a factory using robotic assembly. The reactor vessel can be shipped on a truck and the whole power station located on a site that is just one-tenth the size of large-scale reactor sites. The consortium says their SMR will cost £1.75 Bn and could be delivering power to the grid in 2029. It will last for 60 years and will supply electricity at a cost of less than £60 per 100 kWHr. The government support is very welcome although it probably does not even cover the costs already expended by the consortium. This is an exciting project that could not only help the UK reach its 2050 target but become a major source of export revenues. Several foreign governments have already written letters of intent to Rolls Royce.

When all of these factors have been taken into account, the costs of renewable and nuclear energy may be about the same, but even if they are not, we will still need nuclear to back up the intermittent renewables and keep the lights on when there is no wind or sunshine.

The UK has been relatively successful in decarbonizing its electricity supply and we are above average in terms of the actions we are taking to curb climate change. None the less we must ensure that our energy and transport strategies make numerical as well as political sense and this will involve our expert systems engineers and climate scientists working closely with government and civil service officials. One way this has been successfully achieved in the past is by harnessing the knowledge of the fellows of the Royal Academy of Engineering and the Royal Society. They should be consulted more often, and we should not continue developing strategies under wraps and treating them as being politically sensitive. The Royal Academy of Engineering has in fact scrutinized the costing of the RR Consortium SMRs.

There is a National Grid website that I recommend to readers who are interested in following the UK's progress in decarbonizing electricity. It shows the current and historical percentages of electricity power types delivered on the UK grid http://grid.iamkate.com .You will see on this site that in 2019 the fraction of power generated by wind and solar and hydroelectric increased to 23% and nuclear was maintained at 20%, giving a total of 43% overall for very low carbon generation. This is encouraging and shows that we are on the way to realising our goal of using renewables in combination with nuclear to decarbonize our electricity.

However, there were weekly averages in 2019 where the power from wind and solar fell to below 2 GW, or a fifth of the maximum of about 10 GW when they were operating close to their nominal capacity. This suggests that a backup capability of about 80% of the maximum renewable generation will be needed. I have been unable to find an estimate of what is being assumed for the balance between nuclear and wind and solar, but for a total capability of 50 GW, it would seem to have to fall between 250GW of renewables and zero nuclear, and zero renewables and 50GW of nuclear. Perhaps 100 GW renewables and 30 GW nuclear, or 50GW renewables and 40GW nuclear would seem reasonable. Whatever is decided, a great deal of new capacity will have to be built and the complexity, cost and reliability of the grid that must deal rapidly with the endlessly varying output of the renewables is going to be a major challenge.

The most straightforward and least complicated alternative would be use 100% nuclear, but this would initially be difficult to finance and in any case is politically impossible. When thinking about this, it is interesting to note that some of the plans being made by the

Chinese to reduce carbon include the building of 550GW of nuclear capacity, enough to supply ten times the UK's gross electricity needs.

Another unknown is the increase in total capability needed when all our road transport is electric. We have only just started to build the charging network that will be needed and there is little detailed information about the cost and timescale for this immense project. The network will have to have far more charging points than there are petrol and diesel nozzles and be more distributed than the network of petrol stations, because it takes at least 50 times longer to deliver energy to an electric car. A diesel nozzle delivers energy at an equivalent rate of 25 megawatts compared to the largest car charging points today that are only approaching 0.25 megawatt. Most points supply between 0.005 megawatts and 0.025 megawatts. It will take hours rather than minutes to fully charge a vehicle. Partial charging will of course be faster, but there will have to be charging points in homes and work locations and anywhere else that cars will be left for a significant time. At the end of 2019 there were about 30,000 points in the UK and approaching 40 million vehicles.

There is much to be done and more difficult compromises to be made before we reach our target of zero carbon in 2050, but the government seems to have the right approach in placing highest priority on renewables and nuclear, while continuing to maintain some support for the other options for generation and storage. However, the building of new nuclear will have to be accelerated if we are to succeed.

At least we are now seriously addressing climate change and are above average in setting an example to others of how progress can be made.

Finally, there is another website that is valuable in allowing us to see how the UK is performing relative to other countries. https://www.electricitymap.org/?page=map&solar=false&remote=true&wind=false

It is a world map showing in colour the real time carbon intensity of electricity generation in different countries. The map remains incomplete, but you will see, for example, that the UK is ahead of Germany, the Netherlands and Poland but cannot compete with France, where there is a large fraction of nuclear, or Scandinavia and Iceland where fossil fuels plants have been replaced by hydroelectric and geothermal energy.

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BBSRC invests in world-class bioscience research and training. This research is helping society to meet major challenges, including food security, green energy and healthier, longer lives and underpinning important UK economic sectors, such as farming, food, industrial biotechnology and pharmaceuticals.

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Website: www.esrc.ukri.org

ESRC is the UK's largest funder of research on the social and economic questions facing us today. This research shapes public policy and contributes to making the economy more competitive, as well as giving people a better understanding of 21st century society.

Engineering and Physical Sciences Research Council

Website: www.epsrc.ukri.org

EPSRC invests in world-leading research and postgraduate training across the engineering and physical sciences. This research builds the knowledge and skills base needed to address scientific and technological challenges and provides a platform for future UK prosperity by contributing to a healthy, connected, resilient, productive nation.

Innovate UK

Website: www.gov.uk/government/organisations/innovate-uk

Innovate UK drives productivity and economic growth by supporting businesses to develop and realise the potential of new ideas, including those from the UK's world-class research base. They connect businesses to the partners, customers and investors that can help them turn these ideas into commercially successful products and services, and business growth.

Medical Research Council

Website: www.mrc.ukri.org

MRC is at the forefront of scientific discovery to improve human health. Its scientists tackle some of the greatest health problems facing humanity in the 21st century, from the rising tide of chronic diseases associated with ageing to the threats posed by rapidly mutating micro-organisms.

Natural Environment Research Council

Website: www.nerc.ukri.org

NERC is the driving force of investment in environmental science. Its leading research, skills and infrastructure help solve major issues and bring benefits to the UK, such as affordable clean energy, air pollution, and resilience of our infrastructure.

Research England

Website: www.re.ukri.org

Research England creates and sustains the conditions for a healthy and dynamic research and knowledge exchange system in English universities. Working to understand their strategies, capabilities and capacity; supporting and challenging universities to create new knowledge, strengthen the economy, and enrich society.

Science and Technology Facilities Council

Website: www.stfc.ukri.org

STFC is a world-leading multi-disciplinary science organisation. Its research seeks to understand the Universe from the largest astronomical scales to the tiniest constituents of matter, and creates impact on a very tangible, human scale.

Association of the British Pharmaceutical Industry

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The Association of the British Pharmaceutical Industry (ABPI) represents innovative research-based biopharmaceutical companies, large, medium and small, leading an exciting new era of biosciences in the UK. Our industry, a major contributor to the economy of the UK, brings life-saving and life-enhancing medicines to patients. Our members are researching and developing over two-thirds of the current medicines pipeline, ensuring that the UK remains at the forefront of helping patients prevent and overcome diseases. Topics we focus on include:

- All aspects of the research and development of medicines including clinical research and licensing
- Stratified medicine
- Vaccines, biosimilars, small and large molecules, cell therapy and regenerative medicine

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AIRTO, the Association of Innovation, Research and Technology Organisations, comprises approximately sixty principal organisations operating in the UK's Innovation, Research and Technology (IRT) sector. The IRT sector has a combined turnover of £6.9Bn, employs over 57,000 people and contributes £34Bn to UK GVA. AIRTO's members work at the interface between academia and industry, for both private and public sector clients. Members include independent Research and Technology Organisations, Catapult Centres, Public Sector Research Establishments, National Laboratories, some university Technology Transfer Offices and some privately held innovation companies.

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We are a Trades Union for Management and Professional Staff working in the pharmaceutical, chemical and allied industries.

We have produced a training programme funded by the EU on diversity and helping women managers remain in the workplace after a career break. This training programme is aimed at both men and women and is intended to address the shortfall in qualified personnel in the chemical and allied industries.

We are experts in performance based and field related issues and are affiliated to our counterparts in EU Professional Management Unions.

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AWE plays a crucial role in our nation's defence by providing and maintaining warheads for the UK's nuclear deterrent and delivers advice and guidance on a 24/7 basis to UK government in the area of national security.

We are a centre of scientific, engineering and technological excellence, with some of the most advanced research, design and production facilities in the world. AWE is contracted to the Ministry of Defence (MOD) through a Government-owned-contractor-operated (GOCO) arrangement. While our sites and facilities remain in government ownership, their management, day-to-day operations and maintenance of Britain's nuclear stockpile is contracted to a private company: AWE Management Limited (AWE ML). AWE ML is a consortium comprising three partners: Jacobs Engineering Group, the Lockheed Martin Corporation and Serco Group plc.

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The Biochemical Society works to promote the molecular biosciences; facilitating the sharing of expertise, supporting the advancement of biochemistry and molecular biology and raising awareness of their importance in addressing societal grand challenges. We achieve our mission by :

- bringing together molecular bioscientists;
- supporting the next generation of biochemists;
- promoting and sharing knowledge and
- promoting the importance of our discipline.

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British Antarctic Survey (BAS), an institute of NERC, delivers and enables world-leading interdisciplinary research in the Polar Regions. Its skilled science and support staff based in Cambridge, Antarctica and the Arctic, work together to deliver research that uses the Polar Regions to advance our understanding of Earth as a sustainable planet. Through its extensive logistic capability and know-how BAS facilitates access for the British and international science community to the UK polar research operation. Numerous national and international collaborations, combined with an excellent infrastructure help sustain a world leading position for the UK in Antarctic affairs. For more information visit www.bas.ac.uk @basnews

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The British Ecological Society is an independent, authoritative learned society, and the voice of the UK's ecological community. Working with our members we gather and communicate the best available ecological evidence to inform decision making. We offer a source of unbiased, objective ecological knowledge, and promote an evidence-informed approach to finding the right solutions to environmental questions.

British In Vitro Diagnostics Association (BIVDA)

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BIVDA is the UK industry association representing companies who manufacture and/or distribute the diagnostics tests and equipment to diagnose, monitor and manage disease largely through the NHS pathology services. Increasingly diagnostics are used outside the laboratory in community settings and also to identify those patients who would benefit from specific drug treatment particularly for cancer.

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The British Pharmacological Society is a charity with a mission to promote and advance the whole spectrum of pharmacology. It is the primary UK learned society concerned with drugs and the way they work, and leads the way in the research and application of pharmacology around the world.

Founded in 1931, the Society champions pharmacology in all its forms, across academia, industry, regulatory agencies and the health service. With over 3,500 members from over 60 countries worldwide, the Society is a friendly and collaborative community. Enquiries about the discovery, development and application of drugs are welcome.

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BSAC is a learned society whose members are among the world's leading infectious disease physicians, pharmacists, microbiologists, and nurses.

With more than 45 years of leadership in antibiotic research and education, BSAC is dedicated to saving lives by fighting infection. It does this by supporting a global network of experts via workshops, conferences, evidence-based guidelines, e-learning courses, and its own high-impact international journal.

BSAC also provides national surveillance and susceptibility testing programmes, an outpatient parenteral antimicrobial therapy (OPAT) initiative, research and development grants, and the secretariat for the All-Party Parliamentary Group on Antibiotics.

BSAC has members in 40 nations and active learners in more than 135 countries.

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The British Society for Immunology's mission is to promote excellence in immunological research, scholarship and clinical practice in order to improve human and animal health. We are the leading UK membership organisation working with scientists and clinicians from academia and industry to forward immunology research and application around the world. Our friendly, accessible community of over 3,500 immunologists gives us a powerful voice to advocate for immunological science and health for the benefit of society.

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The British Society of Soil Science (BSSS) or "BS cubed" as it is fondly known was founded in 1947 by a number of eminent British soil scientists. It was formed with the aims: to advance the study of soil; to be open to membership from all those with an interest in the study and uses of soil; and to issue an annual publication.

Nowadays BSSS is an established international membership organisation and charity committed to the study of soil in its widest aspects. The Society acts as a forum for the exchange of ideas and provides a framework for representing the views of soil scientists to other organisations and decision making bodies. It promotes research by organising several conferences each year and by the publication of its two scientific journals, the European Journal of Soil Science, and Soil Use and Management.

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Brunel University London is an international research active university with 3 leading research institutes:

Institute of Energy Futures: Led by Professor Savvas Tassou, the main themes of the Institute are *Advanced Engines and Biofuels, Energy Efficient and Sustainable Technologies, Smart Power Networks*, and *Resource Efficient Future Cities*.

Institute of Materials and Manufacturing: The main themes of research are *Design for Sustainable Manufacturing, Liquid Metal Engineering, Materials Characterisation and Processing, Micro-Nano Manufacturing*, and *Structural Integrity*. The Institute is led by Professor Luiz Wrobel.

Institute of Environment, Health and Societies: Professor Susan Jobling leads this pioneering research institute whose themes are *Health and Environment, Healthy Ageing, Health Economics Synthetic Biology, Biomedical Engineering and Healthcare Technologies*, and *Social Sciences and Health*.

Brunel University London offers a wide range of expertise and knowledge, and prides itself on having academic excellence at the core of its offer, and was ranked in the recent REF as 33rd in the UK for Research Power (average quality rating by number of submissions) and described by The Times Higher Education as one of the real winners of the REF 2014.

Cavendish Laboratory

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The Cavendish Laboratory houses the Department of Physics of the University of Cambridge.

The research programme covers the breadth of contemporary physics

Extreme Universe: Astrophysics, cosmology and high energy physics

Quantum Universe: Cold atoms, condensed matter theory, scientific computing, quantum matter and semiconductor physics

Materials Universe: Optoelectronics, nanophotonics, detector physics, thin film magnetism, surface physics and the Winton programme for the physics of sustainability

Biological Universe: Physics of medicine, biological systems and soft matter

The Laboratory has world-wide collaborations with other universities and industry

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Our vision is integrated design to improve life, wellbeing and performance through science, engineering, technology and psychology. The Institute is one of the largest in the world representing the discipline and profession of Human Factors and Ergonomics. We have sector groups in most industries from defence to aviation and pharmaceuticals that provide expert advice to industry and government. We accredit university courses and consultancy practices and work closely with allied learned societies.

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CTPA is the UK trade association representing manufacturers of cosmetic products and suppliers to the cosmetic products industry. 'Cosmetic products' are legally defined and subject to stringent EU safety laws. CTPA is the authoritative public voice of a vibrant and responsible UK industry trusted to act for the consumer; ensuring the science behind cosmetics is fully understood.

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We bring school students and their teachers

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- Primary; our local **Meet-a-Medic Programme** since 2005

Clifton Scientific Trust Ltd is registered charity in England and Wales 1086933

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The Council for the Mathematical Sciences is an authoritative and objective body that works to develop, influence and respond to UK policy issues affecting mathematical sciences in higher education and research, and therefore the UK economy and society by:

- providing expert advice;
- engaging with government, funding agencies and other decision makers;
- raising public awareness; and
- facilitating communication between the mathematical sciences community and other stakeholders

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The Francis Crick Institute is a biomedical discovery institute dedicated to understanding the fundamental biology underlying health and disease. Its work is helping to understand why disease develops and to translate discoveries into new ways to prevent, diagnose and treat illnesses such as cancer, heart disease, stroke, infections, and neurodegenerative diseases.

The Crick was formed in 2015, and in 2016 it moved into a brand new state-of-the-art building in central London which brings together 1500 scientists and support staff working collaboratively across disciplines.

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Founded in 1992 in memory of the UK's first female Professor of Physics, the Trust is the UK's leading charity dedicated to realising the potential of scientists and engineers returning to research after career breaks for family, caring and health reasons. Recently, we have expanded our remit to incorporate the social sciences and arts & humanities. Our Fellowship programme, working in partnership with universities, UKRI, charities, learned societies and industry, enables individuals to undertake part-time research in universities and research institutes. Fellowships comprise a research project alongside an individually tailored retraining programme, with additional mentoring and support, enabling recipients to re-establish their research credentials, update skills and redevelop confidence, in a suitably supportive environment.

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The Energy Institute (EI) is the chartered professional membership body bringing together expertise for urgent global challenges. Our ambition is that energy, and its critical role in our world, is better understood, managed and valued. We're a unique network with insight spanning the world of energy, from conventional oil and gas to the most innovative renewable and energy efficient technologies. We gather and share essential knowledge about energy, the skills that are helping us all use it more wisely, and the good practice needed to keep it safe and secure. We articulate the voice of energy experts, taking the know-how of around 20,000 members and 200 companies from 120 countries to the heart of the public debate. And we're an independent, not-for-profit, safe space for evidence-based collaboration, an honest broker between industry, academia and policy makers.

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EngineeringUK is an independent organisation that promotes the vital role of engineers, engineering and technology in our society. EngineeringUK partners business and industry, Government and the wider science and technology community: producing evidence on the state of engineering; sharing knowledge within engineering, and inspiring young people to choose a career in engineering, matching employers' demand for skills.

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Fera provides expert analytical and professional services to governments, agrichemical companies, food retailers, manufacturers and farmers to facilitate safety, productivity and quality across the agrifood supply chain in a sustainable and environmentally compatible way.

Fera uses its world leading scientific expertise to provide robust evidence, rigorous analysis and professional advice to governments, international bodies and companies worldwide. Our food integrity, plant health, agri-tech and agri-informatics services ensure that our customers have access to leading edge science, technology and expertise.

First Group

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FirstGroup are the leading transport operator in the UK and North America and each day, every one of our 110,000 employees works hard to deliver vitally important services for our passengers. During the last year around 2.2 billion passengers relied on us to get to work, to school or college, to visit family and friends, and much more.

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GAMBICA is the voice of the laboratory technology, instrumentation, control and automation industries, providing influence, knowledge and community. We offer members a common platform for voicing their opinions and representing their common interests to a range of stakeholders. GAMBICA seeks to spread best-practice and be thought leaders in our sectors.

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The Geological Society is the national learned and professional body for Earth sciences, with 12,000 Fellows (members) worldwide. The Fellowship encompasses those working in industry, academia and government, with a wide range of perspectives and views on policy-relevant science, and the Society is a leading communicator of this science to government bodies and other non-technical audiences.

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Advancing knowledge and setting standards in biomedical science

With over 20,000 members in 61 countries, the Institute of Biomedical Science (IBMS) is the leading professional body for scientists, support staff and students in the field of biomedical science.

Since 1912 we have been dedicated to the promotion, development and delivery of excellence in biomedical science within all aspects of healthcare, and to providing the highest standards of service to patients and the public.

By supporting our members in their practice, we set quality standards for the profession through training, education, assessments, examinations and continuous professional development.

Institute of Food Science + Technology (ifst)

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We are the UK's leading professional body for those involved in all aspects of food science and technology. We are an internationally respected independent membership body, supporting food professionals through knowledge sharing and professional recognition.

Our core aim is the advancement of food science and technology based on impartial science and knowledge sharing.

Our membership comprises individuals from a wide range of backgrounds, from students to experts, working across a wide range of disciplines within the sector.

IKE

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IKE is the UK's professional body for innovators. It accredits and certificates innovation practices. We influence the inter-relationship between education, business, and government through research and collaborative networks. Our Innovation Manifesto highlights our commitment to support the development of innovative people and organisations. IKE runs think-tanks, conducts research, develops new business models and tools and supports organisations to benchmark their innovation capabilities.

Institute of Marine Engineering, Science and Technology (IMarEST)

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Established in London in 1889, the IMarEST is a leading international membership body and learned society for marine professionals, with over 15,000 members worldwide. The IMarEST has an extensive marine network of 50 international branches, affiliations with major marine societies around the world, representation on the key marine technical committees and non-governmental status at the International Maritime Organization (IMO) as well as other intergovernmental organisations.

The Institute of Materials Finishing

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The Institute of Materials Finishing is the premier technical organisation representing industry, academia and individual professionals in both the UK's and global surface engineering and materials finishing sector.

We actively promote continual education and knowledge dissemination by providing both distance learning and tutored training courses, as well as a technical support service. We also provide bespoke courses that are tailored to an employer's specific needs. The Institute also publishes *Transactions of the Institute of Materials Finishing* and a bimonthly newsletter (*IMFormation*), as well as holding regular regional and international technical meetings, symposia and conferences.

Institute of Measurement and Control

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The Institute of Measurement and Control is a professional engineering institution and learned society dedicated to the science and application of measurement and control technology for the public benefit. The InstMC has a comprehensive range of membership grades for individuals engaged in both technical and non-technical occupations. Also, it is licensed by the Engineering Council to assess and register individuals as Chartered Engineers (CEng), Incorporated Engineers (IEng) and Engineering Technicians (EngTech).

The InstMC works to develop the knowledge and skills of individual engineers, fostering communication and advancing the science and practices within the industry.

IOP Institute of Physics

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The Institute of Physics (IOP) is the professional body and learned society for physics in the UK and Ireland. The IOP's mission is to raise public awareness and understanding of physics, inspire people to develop their knowledge, understanding and enjoyment of physics and support the development of a diverse and inclusive physics community. As a charity, the IOP seeks to ensure that physics delivers on its exceptional potential to benefit society.

Institute of Physics and Engineering in Medicine (IPEM)

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IPEM is a registered, incorporated charity for the advancement, in the public interest, of physics and engineering applied to medicine and biology. Its members are medical physicists, clinical and bio-engineers, and clinical technologists. It organises training and CPD for them, and provides opportunities for the dissemination of knowledge through publications and scientific meetings. IPEM is licensed by the Science Council to award CSci, RSci and RSciTech, and by the Engineering Council to award CEng, IEng and EngTech.

IChemE — The Institution of Chemical Engineers

The Institution of Chemical Engineers (IChemE) advances chemical engineering's contribution worldwide for the benefit of society. We support the development of chemical engineering professionals and provide connections to a powerful network of around 35,000 members in 100 countries.

We support our members in applying their expertise and experience to make an influential contribution to solving major global challenges, and are the only organisation to award Chartered Chemical Engineer status and Professional Process Safety Engineer registration.

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Kuala Lumpur | London | Melbourne | Rugby | Singapore | Wellington

IET — The Institution of Engineering and Technology

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The IET is a world leading professional organisation, sharing and advancing knowledge to promote science, engineering and technology across the world. Dating back to 1871, the IET has over 163,000 members in 127 countries with offices in Europe, North America, and Asia-Pacific.

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LGC is a global leader in the life sciences tools sector, including human healthcare and applied markets (food, agbio and the environment). LGC provides a comprehensive range of measurement tools, proficiency testing schemes, supply chain assurance standards and specialty genomics tools (oligos, PCR tools, NGS reagents), underpinned by leading analytical and measurement science capabilities. Under the Government Chemist function, LGC fulfils specific statutory duties as the referee analyst and provides advice for Government and the wider analytical community on the implications of analytical measurement for matters of policy, standards and regulation. LGC is also the UK's National Measurement Laboratory for chemical and bio-measurement.

With headquarters in Teddington, South West London, LGC has laboratories and sites across Europe, the US, China, Brazil, India, and South Africa.

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L'Oréal employs more than 3,800 researchers world-wide and dedicates over €877 million each year to research and innovation in the field of healthy skin and hair. The company supports women in science research through the L'Oréal UNESCO For Women In Science Programme and engages young people with science through the L'Oréal Young Scientist Centre at the Royal Institution. L'Oréal also collaborates with a vast number of institutions in the UK and globally.

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As the world's oldest active biological society, the Linnean Society is an essential forum and meeting point for those interested in the natural world. The Society holds regular public lectures and events, publishes three peer-reviewed journals, and promotes the study of the natural world with several educational initiatives. The Society is home to a world famous library and collection of natural history specimens. The Society's Fellows have a considerable range of biological expertise that can be harnessed to inform and advise on scientific and public policy issues.

A Forum for Natural History

London School of Hygiene & Tropical Medicine
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The London School of Hygiene & Tropical Medicine (LSHTM) is a world-leading centre for research and postgraduate education in public and global health with over 4,000 students and more than 1,300 staff working in over 100 countries across the world – including at two MRC Units in The Gambia and Uganda which joined LSHTM in 2018. Our depth and breadth of expertise encompasses many disciplines, and we are one of the highest-rated research institutions in the UK.

Marine Biological Association

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Since 1884 the Marine Biological Association has been delivering its mission *'to promote scientific research into all aspects of life in the sea, including the environment on which it depends, and to disseminate to the public the knowledge gained.'* The MBA represents its members in providing a clear independent voice to government on behalf of the marine biological community. It also has an extensive research programme and a long history as an expert provider of advice for the benefit of policy makers and wider society.

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The Institution provides politicians and civil servants with information, expertise and advice on a diverse range of subjects, focusing on manufacturing, energy, environment, transport and education policy. We regularly publish policy statements and host political briefings and policy events to establish a working relationship between the engineering profession and parliament.

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Website: www.metoffice.gov.uk

The Met Office doesn't just forecast the weather on television. Our forecasts and warnings protect UK communities and infrastructure from severe weather and environmental hazards every day – they save lives and money. Our Climate Programme delivers evidence to underpin Government policy through the Met Office Hadley Centre. Our Mobile Meteorological Unit supports the Armed Forces around the world. We build capacity overseas in support of international development. All of this built on world-class environmental science.

Contact: Policy Officer
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The Microbiology Society is a membership charity for scientists interested in microbes, their effects and their practical uses. It is one of the largest microbiology societies in Europe with a worldwide membership based in universities, industry, hospitals, research institutes and schools.

Our principal goal is to develop, expand and strengthen the networks available to our members so that they can generate new knowledge about microbes and ensure that it is shared with other communities. The impacts from this will drive us towards a world in which the science of microbiology provides maximum benefit to society.

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The National Physical Laboratory (NPL) is the United Kingdom's national measurement institute, an internationally respected and independent centre of excellence in research, development and knowledge transfer in measurement and materials science. For more than a century, NPL has developed and maintained the nation's primary measurement standards - the heart of an infrastructure designed to ensure accuracy, consistency and innovation in physical measurement.

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We challenge the way people think about the natural world – its past, present and future

We use our unique collection and unrivalled expertise to tackle the biggest challenges facing the world today.

We are leaders in the scientific understanding of the origin of our planet, life on it and can predict the impact of future change.

We study the diversity of life and the delicate balance of ecosystems to ensure the survival of our planet.

We help enable food security, eradicate disease and manage resource scarcity.

We inspire people to engage with science to solve major societal challenges.

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The University of Northampton is an institution committed to science education through initial teacher training, a STEM Ambassador network which works within the community and teaching and research to doctoral level. We are an Ashoka U 'Changemaker Campus' status university recognising our commitment to social innovation and entrepreneurship.

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With 43,000 students and campuses in Nottingham, China and Malaysia, The University of Nottingham is 'the nearest Britain has to a truly global university'. With more than 97 per cent of research at the University recognised internationally according to the Research Excellence Framework 2014, the University is ranked in the top 1% of the world's universities by the QS World University Rankings.

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The Nutrition Society is a not for profit, membership organisation which is dedicated to delivering its mission of advancing the scientific study of nutrition and its application to the maintenance of human and animal health. Highly regarded by the scientific community, the Society is one of the largest learned societies for nutrition in the world and anyone with a genuine interest in the science of human or animal nutrition can become a member.

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As the largest network of physiologists in Europe, with academic journals of global reach, we continue our 140-year tradition of being at the forefront of the life sciences.

We bring together scientists from over 60 countries, and our Members have included numerous Nobel Prize winners from Ivan Pavlov to John O'Keefe.

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Prospect is an independent, thriving and forward-looking trade union with 117,000 members across the private and public sectors and a diverse range of occupations. We represent scientists, technologists and other professions in the civil service, research councils and private sector.

Prospect's collective voice champions the interests of the engineering and scientific community to key opinion-formers and policy makers. With negotiating rights with over 300 employers, we seek to secure a better life at work by putting members' pay, conditions and careers first.

QUADRUM INSTITUTE

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Opening fully in mid-2018, the Quadram Institute will be an interdisciplinary research centre capitalising on the academic excellence and clinical expertise of the Norwich Research Park. Its mission is to understand how food and the gut microbiota link to the promotion of health and preventing diet and age related diseases. The Quadram Institute brings together fundamental and translational science with a clinical research facility for human trials and one of Europe's largest gastrointestinal endoscopy units. This will synergise interactions between basic and clinical research, delivering a step change in the understanding of the role of food in health.

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As the UK's national academy for engineering, we bring together the most successful and talented engineers for a shared purpose: to advance and promote excellence in engineering. We have four strategic challenges: drive faster and more balanced economic growth; foster better education and skills; lead the profession; and promote engineering at the heart of society.

Contact: Office of the Science Directorate
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RBG Kew is a centre of global scientific expertise in plant and fungal diversity, conservation, and sustainable use, housed in two world-class gardens. Our scientific vision is to document and understand global plant and fungal diversity and its uses, bringing authoritative expertise to bear on the critical challenges facing humanity today.

Kew's strategic priorities for science are:

1. To document and conduct research into global plant and fungal diversity and its uses for humanity.
2. To curate and provide data-rich evidence from Kew's unrivalled collections as a global asset for scientific research.
3. To disseminate our scientific knowledge of plants and fungi, maximising its impact in science, education, conservation policy and management.

These priorities enable us to curate, use, enhance, explore and share Kew's global resource, providing robust data and a strong evidence base for our UK and global stakeholders. Kew is a non-departmental government body with exempt charitable status, partially funded by Defra.

The Royal Institution
Science Lives Here

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www.richannel.org
Twitter: ri_science

The Royal Institution (Ri) has been at the forefront of public engagement with science for over 200 years and our purpose is to encourage people to think further about the wonders of science. We run public events and the famous CHRISTMAS LECTURES®, a national programme of Masterclasses for young people in mathematics, engineering and computer science, educational activities at the L'Oréal Young Scientist Centre and policy discussions with science students. And through the Ri Channel we share the stories behind cutting-edge science with people around the world.

THE ROYAL SOCIETY

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The Royal Society is the academy of science in the UK and the Commonwealth comprising 1400 outstanding individuals representing the sciences, engineering and medicine. The Society has played a part in some of the most fundamental, significant and life-changing discoveries in scientific history and Royal Society scientists continue to make outstanding contributions to science across the wide breadth of research areas. Through its Fellowship and permanent staff, it seeks to ensure that its contribution to shaping the future of science in the UK and beyond has a deep and enduring impact, supporting excellence in science and encouraging the development and use of science for the benefit of humanity.

Royal Society of Biology

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The Royal Society of Biology is a single unified voice, representing a diverse membership of individuals, learned societies and other organisations. We are committed to ensuring that we provide Government and other policy makers – including funders of biological education and research – with a distinct point of access to authoritative, independent, and evidence-based opinion, representative of the widest range of bioscience disciplines. Our vision is of a world that understands the true value of biology and how it can contribute to improving life for all.

Royal Society of Chemistry

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The Royal Society of Chemistry is the world's leading chemistry community, advancing excellence in the chemical sciences. With over 50,000 members and a knowledge business that spans the globe, we are the UK's professional body for chemical scientists; a not-for-profit organisation with 170 years of history and an international vision of the future. We promote, support and celebrate chemistry. We work to shape the future of the chemical sciences – for the benefit of science and humanity.

society for applied microbiology

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*Sf*AM utilises the expertise of its international membership to advance, for the benefit of the public, the application of microbiology to the environment, human and animal health, agriculture, and industry. Our values include equality, diversity and inclusivity; collaboration to amplify impact; scientific integrity; evidence-based decision-making and political neutrality. With Wiley-Blackwell, *Sf*AM publishes five internationally acclaimed journals.

Society for Underwater Technology

SUT Society for Underwater Technology

Society for Underwater Technology
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Website: www.sut.org

The SUT is a multidisciplinary learned society that brings together individuals and organisations with a common interest in underwater technology, ocean science, and offshore/subsea engineering. The society was founded in 1966 and has members from over 40 countries, including engineers, scientists, other professionals and students working in these areas.

Society of Chemical Industry

SCI: where science meets business

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Website www.soci.org

Established by Royal Charter in 1881, SCI is a unique multi-disciplinary community. Set up by a prominent group of forward thinking scientists, inventors and entrepreneurs, SCI continues to be a multi-science and industry network based around chemistry and related sciences. Our charitable objective is to promote links between science and industry for the benefit of society. Our passion is invention and creation.

We deliver our charitable objective by:

- Supporting the commercial application of science into industry
- Tackling global challenges across Agrifood, Energy, Environment, Health and Materials

Society of Cosmetic Scientists

SCS Society of Cosmetic Scientists

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Secretary General
Society of Cosmetic Scientists
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Advancing the science of cosmetics is the primary objective of the SCS. Cosmetic science covers a wide range of disciplines from organic and physical chemistry to biology and photo-biology, dermatology, microbiology, physical sciences and psychology.

Members are scientists and the SCS helps them progress their careers and the science of cosmetics ethically and responsibly. Services include publications, educational courses and scientific meetings.

Society of Maritime Industries

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The Society of Maritime Industries (SMI) is the voice of the UK's maritime engineering and business sector. Promoting and supporting companies in Commercial Marine, Maritime Defence & Security, Ports & Terminals Infrastructure, Marine Science & Technology, Maritime Autonomous Systems and Digital Technology.

UK INNOVATION & SCIENCE SEED FUND

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Website: https://ukinnovationscience seedfund.co.uk/

The **UK Innovation & Science Seed Fund** is a leading patient capital investor with more than £330 million private investment leveraged to date. The Fund works to build technology companies from the earliest stage by working closely with its partners led by STFC, BBSRC, NERC and Dstl, with the National Research and Innovation Campuses they support, and with entrepreneurial science-led teams. UK Innovation & Science Seed Fund is also closely aligned with the Catapults and InnovateUK, helping to commercialise key technological advances in industrial biotech, agricultural technology, healthcare, medicine, clean energy, materials, artificial intelligence, software and space.

Understanding ANIMAL RESEARCH

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Understanding Animal Research is a not-for-profit organisation that explains why animals are used in medical, veterinary, environmental and other scientific research. We aim to achieve a broad understanding of the humane use of animals in medical, veterinary, scientific and environmental research in the UK. We work closely with policymakers to ensure regulation is effective and are a trusted source of information for the national and international media. We are funded by our members who include universities, professional societies, trade unions, industry and charities.

University of Essex

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Established in 1964, the University of Essex is ranked as one of the Top 20 universities in the Research Excellence Framework and is awarded Gold in the Teaching Excellence Framework. It is home to world-leading expertise in analytics and data science, with research peaks spanning the social sciences, sciences, and humanities. Pioneers of quantitative methods and artificial intelligence techniques, Essex is also in the UK top 10 for Knowledge Transfer Partnerships, and works with businesses to embed innovation into operations, through KTPs, knowledge exchange and contract research.

Universities Federation for Animal Welfare

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Website: www.ufaw.org.uk
Registered in England Charity No: 207996

UFAW, the international animal welfare science society, is an independent scientific and educational charity. It works to improve animal lives by:

- supporting animal welfare research
- educating and raising awareness of welfare issues in the UK and overseas
- producing the quarterly scientific journal Animal Welfare and other high-quality publications on animal care and welfare
- providing advice to government departments and other concerned bodies.

The Welding Institute

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The Welding Institute is the leading institution providing engineering solutions and knowledge transfer in all aspects of manufacturing, fabrication and whole-life integrity management.

Industrial membership provides access to innovative problem-solving from one of the world's foremost independent research and technology organisations.

Non-Corporate services include membership and registration, education, training and certification for internationally recognised professional development and personnel competence assurance.

TWI provides Members and stakeholders with authoritative and impartial expert advice, knowhow and safety assurance through engineering, materials and joining technologies.

SCIENCE DIARY

PARLIAMENTARY AND SCIENTIFIC COMMITTEE – ALL-PARTY PARLIAMENTARY GROUP

Tel: 020 7222 7085
Email: office@scienceinparliament.org.uk
www.scienceinparliament.org.uk
follow us on Twitter @ParlSciCom

Monday 9 March **STEM for BRITAIN**

Evening Discussion
Meetings at 5.30pm, followed by dinner

Monday 30 March: **Autonomous Vehicles**
Monday 11 May: **Non-Tumour Cancers and Precision Medicine and Genome Mapping**
Monday 15 June: **Healthy Ageing**

THE PHYSIOLOGICAL SOCIETY

Tuesday 31 March 2020

Improving Health and Wellbeing:
Opportunities for Public Health Scotland
Burns Room, Scottish Parliament
The Royal Society of Edinburgh and The Physiological Society are jointly holding a Parliamentary Discussion and Reception, hosted by Lewis Macdonald MSP, Convener of the Scottish Parliament Health and Sport Committee, on 31 March 2020 from 5:30pm.
The launch of Public Health Scotland in April represents a huge shift in Scotland's approach to public health. This panel discussion at the Scottish Parliament will look to ensure we harness the opportunity of this new body, and also that public health guidance is informed by the latest research.
Please register online:
www.eventbrite.co.uk/e/91301608569

ROYAL SOCIETY OF BIOLOGY

10th Anniversary Gala Dinner
Tuesday 3 March, 6.30pm
The Science Museum, Exhibition Rd, South Kensington, London SW7 2DD
Lifetime Achievement Award to Sir David Attenborough
Speakers include the Minister of Universities and Science

Accreditation Conference 2020: Striving for Excellence
Wednesday 29 April, 11.00am - 4.00pm
Central Hall Westminster, Storey's Gate, London SW1H 9NH
Bringing together university representatives and industry employers to discuss best practice in higher education

Degree Accreditation Awards Ceremony 2020
Wednesday 29 April, 7:00pm - 10:00pm
Terrace Pavillion, Houses of Parliament, London SW1A 0AA
A celebration of biosciences in higher education in the UK and internationally

Royal Society of Biology Annual General Meeting
Wednesday 6 May, 1.00pm - 4:00pm
20 Bedford Way, London WC1H 0AL
The RSB AGM and Charter Lecture, with a presentation of the Trustee's Report and Accounts

Parliamentary Links Day 2020
Tuesday 14 July, 9:00am - 12.30pm
The Attlee Suite, Portcullis House, Houses of Parliament,
London SW1A 2LW
Save the date for this annual event, organised to strengthen dialogue with Parliament on issues faced by the science and engineering community

ROYAL SOCIETY

Details of all events can be found on the events calendar at events@royalsociety.org
For scientific meetings queries:
scientific.meetings@royalsCociety.org

THE ROYAL INSTITUTION

Details of all events and booking information can be found at www.rigb.org/whats-on.

ROYAL ACADEMY OF ENGINEERING

Details all events can be found at
https://www.raeng.org.uk/events

THE NUTRITION SOCIETY

Summer Conference 2020
Taking place in Aberdeen on 13-16 July 2020, the conference will explore 'Protein: Sources, Benefits and Global Challenges'.

For full details visit:
https://www.nutritionsociety.org/events/summer-conference-2020-protein-sources-benefits-and-global-challenges

Other conferences, training, event details and booking information can be found on the website at https://www.nutritionsociety.org

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Royal Society of Biology

10 YEARS A Decade of Growth

This year we are celebrating 10 years since the formation of the Royal Society of Biology in its current form, and 40 years since the then Institute of Biology was granted its Royal Charter.

The RSB is a charity with 18,000 individual members and nearly 100 member organisations within the biosciences, representing biologists and biology in all its forms.

Our vision is of a world that understands the true value of biology, and how it can contribute to improving life for all and solve some of society's global challenges.

We're celebrating this milestone by honouring Sir David Attenborough HonFRSB with a Lifetime Achievement Award.

We're also pleased to welcome Nobel Laureate Sir Paul Nurse, Rt Hon Greg Clark MP and Stephen Metcalfe MP at our upcoming Anniversary Gala dinner, to help celebrate this milestone year.

Find out more about our anniversary celebrations online **anniversary.rsb.org.uk**

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rsb.org.uk

Registered Charity No. 277981
Incorporated by Royal Charter