fst journal

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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

COUNCIL AND TRUSTEES

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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CONTENTS

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Roger Penrose is awarded Nobel Prize

Professor Roger Penrose, Emeritus Professor at the Mathematical Institute of the University of Oxford, as well as Honorary Fellow of St John's College, Cambridge, and Honorary Doctor of Cambridge University, has jointly won the 2020 Nobel Prize in Physics for the discovery that black hole formation is a robust prediction of the general theory of relativity. The Royal Swedish Academy of Sciences made the announcement on 6 October.

According to the Nobel Prize website: "Penrose used ingenious mathematical methods in his proof that black holes are a direct consequence of Albert Einstein's general theory of relativity."

Einstein himself did not believe that black holes really existed. But in January 1965, ten years after Einstein's death, Penrose proved that black holes really can form and described them in detail.

Lord Martin Rees, Astronomer Royal and a member of the Council of the Foundation for Science and Technology, said: "Penrose is amazingly original and inventive, and has contributed creative insights for more than 60 years. It was Penrose, more than anyone else, who triggered the renaissance in relativity in the 1960s through his introduction of new mathematical techniques."

He shares the 2020 Physics Nobel with Reinhard Genzel and Andrea Ghez who developed methods to see through the huge clouds of interstellar gas and dust to the centre of the Milky Way.

BISWARUP GANGULY (CC -BY-3.0) VIA WIKIMEDIA COMMONS

Roger Penrose: "ingenious mathematical methods" in his work on black holes

UK Space Agency to track space junk

Seven pioneering projects which will develop new sensor technology or artificial intelligence to monitor hazardous space debris have been announced by the UK Space Agency.

The UK Space Agency and Ministry of Defence have also announced the next step in their joint initiative to enhance the UK's awareness of events in space.

Estimates of the amount of space debris in orbit vary, from around 900,000 pieces of space junk larger than 1cm to over 160 million orbital objects in total. Only a fraction of this debris can currently be tracked and avoided by working satellites. The UK has a significant opportunity to benefit from the new age of satellite megaconstellations – vast networks made up of hundreds or even thousands of spacecraft – so it is more important than ever to effectively track this debris.

Today's investments will help bolster the UK's capabilities to track this space junk and monitor the risks of potentially dangerous collisions with satellites or even the crewed International Space Station.

Projects backed today include Lift Me Off who will develop and test machine learning algorithms to distinguish between satellites and space debris, and Fujitsu who are combining machine learning and quantum inspired processing to improve mission planning to remove debris.

DAVID.SHIKOMBA (CC BY-SA 3.0), VIA WIKIMEDIA COMMONS

There may be 160 million pieces of space debris currently in Earth orbit

The funding coincides with the signing of a partnership agreement between the Ministry of Defence and UK Space Agency to work together on space domain awareness. This civil and military collaboration aims to bring together data and analysis from defence, civil and commercial space users to better understand what is happening in orbit in order to ensure the safety and security of UK licensed satellites.

Modelling the path of megastorms

The results of scientific research will make it easier to predict the path of some of the world's most powerful storms, enabling communities to better protect themselves from severe flooding.

Mesoscale convective systems (MCSs) are 'megastorms' that affect large parts of the world, including Africa, Australia, Asia and the Americas, causing human and livestock deaths plus major damage to infrastructure.

They can potentially:

- last from several hours up to two days
- release energy equivalent to the UK consumption for an entire year
- be bigger than the size of England and travel 1,000 km in distance
- unleash over 100 mm of rainfall in just an hour.

In Sahelian Africa, these extreme storms have tripled in frequency since the 1980s due to global warming.

Until now, it was thought that the path of these complex weather systems was largely unpredictable. However, a new study by the UK Centre for Ecology & Hydrology (UKCEH) has found that land surface conditions frequently affect the direction and intensity of megastorms after they have formed.

The research is now helping scientists to develop online tools to better forecast the path and strength of an approaching storm, which will inform alert systems for communities across Africa, providing them with up to six hours' warning. This includes Senegal, where UKCEH is working with the national meteorological service, ANACIM, to see how useful very short-term forecasts are for local emergency responses.

Klein C and Taylor CM (2020) *Dry soils can intensify mesoscale convective systems.* Proceedings of the National Academy of Sciences (PNAS). www.pnas.org/content/117/35/21132

Project creates AI tools to optimise development policies

A project led by ESRC-Turing Fellow Omar Guerrero, with his research partner, Professor Gonzalo Castañeda of the Center for Research and Teaching in Economics in Mexico, has developed a suite of analytical tools that can successfully model the impact of a variety of policy decisions on development indicators.

The United Nation's Sustainable Development Goals (SDGs) aim "to promote prosperity while protecting the planet". These SDGs address the many global challenges faced by humanity, such as poverty, inequality, access to healthcare and education, climate change, environmental degradation, building resilient infrastructure, creating strong institutions, and more.

Modelling the complex scenarios involved in achieving these goals is impossible using traditional economics and statistical techniques, notes the Alan Turing Institute. But this is exactly the sort of long-running policy challenge where cutting-edge data science and artificial intelligence technology can make a huge impact.

In collaboration with the United Nations Development Programme (UNDP), the technology, called Policy Priority Inference, is being adopted by state governments in Latin America to support the effective prioritisation of their public policies to optimise sustainable development. "The results of this project show the potential the Policy Priority Inference model has for providing governments with concrete information on how to increase the effectiveness of public spending and accelerate the achievement of development goals," says Annabelle Sulmont, Public Policy Project Coordinator for the UNDP office in Mexico.

www.turing.ac.uk/research/impact-stories/supercharging-sustainable-development

UKRI funds cutting-edge recycling

Projects to reduce landfill and incineration of waste plastics and schemes to recycle waste into new, sustainable plastics have received a funding boost.

The UK Research and Innovation (UKRI) Industrial Strategy Challenge Fund is investing £20 million in four cutting edge recycling plants.

These plants will increase the available recycling capacity in the UK and expand the range of plastics being recycled, as opposed to being sent to landfill or incineration, or exported overseas for disposal.

The £20 million investment from the Industrial Strategy Challenge Fund, along with over £65 million of industry investment, represents the largest investment the UK has made in plastic packaging recycling technologies.

The technologies include a hydrothermal liquefaction process to convert waste plastic into chemicals and oils for use in the manufacture of new plastic, a thermal cracking procedure to transform end-of-life plastics into hydrocarbon oil that can be used in plastics production, and a depolymerising facility that extracts colour from waste allowing easier reuse.

The funding forms part of UKRI's Smart Sustainable Plastic Packaging (SSPP) challenge, which aims to increase the amount of recyclable plastic packaging and improve UK productivity in plastics, leading to a reduction in plastic waste entering the environment.

www.ukri.org/innovation/industrial-strategy-challenge-fund/smart-sustainable-plastic-packaging

Keeping safe and informed online

A new research centre has developed a wide range of tools to keep people safe and informed online. These include automated tools to flag online harms in social media and a map to identify and avoid different threat such as fraud or disinformation.

Researchers at the National Research Centre on Privacy, Harm Reduction and Adversarial Influence online (REPHRAIN), will also develop new methods to protect against micro-targeting, a tactic used to gather data about individuals, and a Data Advice Bureau to help citizens navigate online spaces safely.

The centre brings together researchers from: the universities of Bristol, Edinburgh, Bath, King's College London and University College London. It will work with partners across industry, policy and the third sector to develop measures to empower individual citizens regarding their privacy and online safety.

Researchers will explore the differing online harms to which diverse groups of people can be exposed, the effectiveness of privacy and online safety measures, and how to balance risks while improving citizens' ability to participate fully in the growing digital economy.

Arctic summer set to be 'ice-free by 2035'

A new study supports predictions that the Arctic could be free of sea ice by 2035.

High temperatures in the Arctic during the last interglacial – the warm period around 127,000 years ago – have puzzled scientists for decades. Now the UK Met Office's Hadley Centre climate model has enabled an international team of researchers to compare Arctic sea ice conditions during the last interglacial with present day. Their findings are important for improving predictions of future sea ice change.

During spring and early summer, shallow pools of water form on the surface of Arctic sea-ice. These 'melt ponds' are important for how much sunlight is absorbed by the ice and how much is reflected back into space. The new Hadley Centre model is the UK's most advanced physical representation of the Earth's climate and a critical tool for climate research and incorporates sea-ice and melt ponds.

Using the model to look at Arctic sea ice during the last interglacial, the team concludes that the impact of intense springtime sunshine created many melt ponds, which played a crucial role in sea-ice melt. A simulation of the future using the same model indicates that the Arctic summer may become sea ice-free by 2035.

Sea ice-free Arctic during the Last Interglacial supports fast future loss **by Guarino MV *et al* (2020) www.nature.com/articles/s41558-020-0865-2**

THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

THE FOUNDATION FUTURE LEADERS ONLINE CONFERENCE 2020

Government, research, industry – looking to the future

Join leaders of these three key sectors of our economy in a series of free online sessions. Hear them set out how they see their disciplines developing. These meetings are aimed at early- to mid-career professionals. Come and debate the direction of travel with fellow future leaders.

Keynote speakers:

Tuesday 17 November

Sir Patrick Vallance, *Government Chief Scientific Adviser*

Wednesday 18 November

Dr Loubna Bouarfa, *Founder and CEO, Okra Technologies;*

Steve Rees, *Vice-President for Discovery Biology, AstraZeneca*

Thursday 19 November

Professor Dame Nancy Rothwell, *Vice-Chancellor, University of Manchester*

Taking place from **10.00-12.00 am** each morning, these sessions will address vital questions such as:

- How does Government use science?
- How does society encourage innovation in industry?
- What role does a university have in tomorrow's world?

In addition to the keynote speakers, the panel sessions will feature mid-career professionals who will bring their insights to the discussion. We invite you to add your own contributions to the debate.

For more information, and to register, visit the Foundation's website: **www.foundation.org.uk/Events/Upcoming**

The Foundation for Science and Technology is a UK charity, providing an impartial platform for debate of policy issues that have a science, research, technology or innovation element. The Foundation Future Leaders Programme brings together a cohort of mid-career professionals drawn from universities, industry and the civil service to develop links and further their understanding of how science and research are conducted, and how they feed into the policy process.

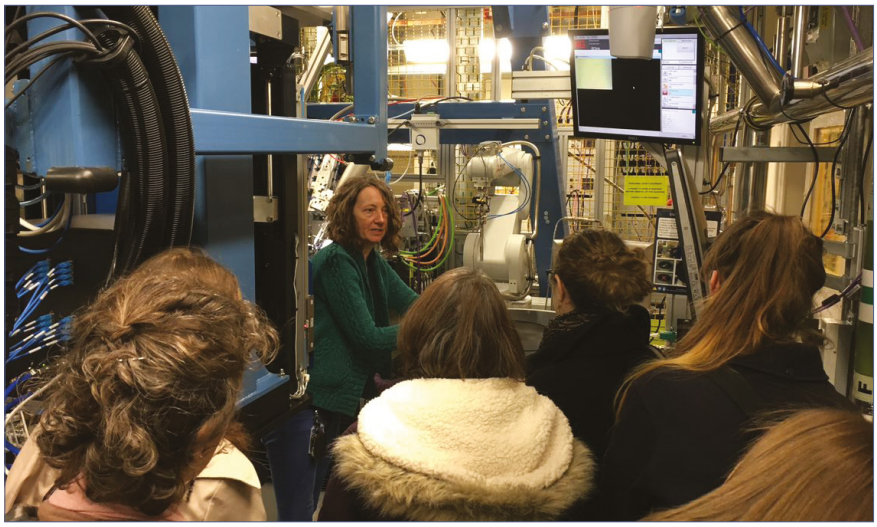
FUTURE LEADERS PROGRAMME

In late 2019, the Foundation for Science and Technology established a Future Leaders Programme to help early career professionals in public service, industry and research to meet, understand each other's worlds and build links across their different sectors.

Building a future in science and innovation

The Foundation Future Leaders programme is approaching the culmination of its first year with an online conference in November. Keynote speakers include Government Chief Scientific Adviser Sir Patrick Vallance and the President and Vice-Chancellor of Manchester University Dame Nancy Rothwell. Originally envisaged as a single full-day event in central London, it has been reconfigured in response to the Covid-19 pandemic and will now take place as three virtual sessions on successive days in mid-November. More details on the page opposite.

For many years, the Foundation for Science and Technology has provided a neutral venue for discussion about science, technology and innovation. It has offered a forum for senior representatives of different economic sectors to come together, network and debate current topics.



Visiting the Diamond Synchrotron, Harwell Science Campus, December 2019.

A continuing role

For the Foundation to play a continuing role in policy-making and industrial formation, it must interact with successive generations of those actively involved in making those decisions, both today and in the years to come. For that reason, securing engagement from a younger generation of industrial managers, civil servants and researchers is crucial. The establishment of the Foundation Future Leaders programme in 2019 was a response to that challenge.

The programme brought together early- and mid-career professionals from different parts of the economy – specifically the civil service, the wider public sector, industry and research – to share insights and experiences, and to enable networking which could continue after the formal programme ends. An added feature was to focus on the career paths of current leaders in these areas, which might stimulate ideas for the programme participants about their own future progression.

Visits were arranged to Harwell, The Wellcome Trust and the Palace of Westminster to explore how different parts of our economy work. When the lockdown began the meetings moved online, so members of the programme were still able to benefit from discussions with senior personnel in the Royal Society of Edinburgh, GSK and others.

The November conference will showcase the interactions between the different parts of the UK's science and innovation landscape. Each session will include members of the current programme and is aimed at their peers across the country.

Next year

The Foundation is now starting to recruit for next year's programme, Applications from interested individuals are being accepted from the beginning of November. More details of how to apply can be found at: **www.foundation.org.uk/Future-Leaders**. Once again, we are hoping to bring together a dynamic group of young leaders from government, industry and research that can work together and learn how to make lasting links with other professionals across different economic sectors. We are hoping to get under way early in the New Year.

The 2021 programme will draw on the insights of this first pilot year. The experience of running a series of events and encouraging networking in the shadow of Covid-19 means that next year's activities can go ahead as a judicious mix of online and – when appropriate – face-to-face events.

The wider Foundation community have already benefited from the Foundation Future Leaders programme. One of its features is to involve these younger leaders in the main Foundation events where they can network with established players in the fields of science and innovation while offering their own insights and aspirations into the discussions. They have become a regular feature in FST events. □

Evening events debating key topics in science, technology and policy are one aspect of the Foundation's activities. Others are described on the FST website.

Creating an interface for science, innovation and policy

The Foundation is developing its website as a resource which brings together a range of different activities. As well as records of the talks and presentations given at its major events, it houses the online edition of *FST Journal*. Newer developments include regular podcasts and blogs.

Podcasts

The Foundation for Science and Technology podcast is a one-to-one discussion exploring aspects of science, technology and innovation, and links to policy. Lasting around 20 minutes, the podcasts can bring out in more depth issues covered in our events, along with one-off interviews on topics of interest.

In September 2020, for example, Professor Sir Venki Ramakrishnan, President of the Royal Society, discussed the state of UK science, science advice to the UK Government during the coronavirus pandemic, and how Brexit might affect UK science. The podcast can be found at: **www.foundation.org.uk/Podcasts/2020/Professor-Sir-Venki-Ramakrishnan,-President-of-the**

Blogs

The Foundation for Science and Technology blog site publishes weekly blog posts discussing and exploring different aspects of science, technology and innovation, and links to policy. Individuals write between 700-1,200 words about their topic of expertise, often linking to our upcoming or recent events.

In September 2020, for example, Tom McNeil, Strategic Adviser to the West Midlands Police & Crime Commissioner, discussed the emergence of predictive policing. He explained the West Midlands Police's approach to AI policing which includes establishing a transparent data ethics committee.

The blog post can be found here: **www.foundation.org.uk/Blog/2020/The-emergence-of-predictive-policing---the-nationa** □

All FST blogs and podcasts can be found at: **www.foundation.org.uk**

RECENT PODCASTS

Chi Onwurah MP, Shadow Minister for Science, Research and Digital
How government draws on scientific advice and the use of science during the Covid-19 pandemic.
www.foundation.org.uk/Podcasts/2020/Chi-Onwurah-MP-Science-and-Politics

Tom McNeil, Strategic Adviser to the West Midlands Police and Crime Commissioner
The use of Artificial Intelligence in policing.
www.foundation.org.uk/Podcasts/2020/Tom-McNeil,-Strategic-Advisor-to-the-West-Midlands

Professor Judith Petts CBE, Vice-Chancellor, University of Plymouth
Preparing for the new academic year in times of Covid.
www.foundation.org.uk/Podcasts/2020/Professor-Judith-Petts-CBE-University-teaching-dur

Dr Michael Short, Chief Scientific Adviser, Department for International Trade
The role of science and evidence in international trade.
www.foundation.org.uk/Podcasts/2020/Dr-Michael-Short-Science-and-evidence-in-internati

Professor Richard Jones, Professor of Materials Physics and Innovation Policy, University of Manchester
Variation of R&D intensity across the UK and the potential for 'Levelling Up' of R&D.
www.foundation.org.uk/Podcasts/2020/Professor-Richard-Jones-R-D-Roadmap-and-Levelling

Dr Stuart Fancey, Director of Research and Innovation, Scottish Funding Council
R&D in Scotland and implications of UK Government's R&D Roadmap.
www.foundation.org.uk/Podcasts/2020/Dr-Stuart-Fancey-The-R-D-Roadmap-and-implications

Stephen Phipson, Chief Executive, MakeUK
Skills resilience, retraining at work, and the role of MakeUK.
www.foundation.org.uk/Podcasts/2020/Stephen-Phipson,-MakeUK-Skills-resilience

The podcasts can bring out in more depth issues covered in our events, along with one-off interviews.

GUEST EDITORIAL

Metrology, the science of measurement, enables innovation across most, if not all sectors, from health to energy, the environment, advanced manufacturing and digital.

Measurement with confidence

Pete Thompson

The National Physical Laboratory (NPL) delivers world-class measurement expertise and is one of six laboratories that make up the National Measurement System. This measurement infrastructure is the invisible glue that binds together science and technology and enables progress.

It is akin to the road network; it allows the smooth passage of traffic, or in this case measurements, which add value to the economy and quality of life as well as enabling new technologies that solve national and global challenges. For example, NPL's measurement scientists, alongside a group of multidisciplinary chemists, physicists and biologists, have addressed one of the greatest challenges in the health sector, which is to develop a reproducible, standardised way to fully map tumours with great precision. This ground-breaking project has progressed with impressive speed and achieved some remarkable results. These advancements are set to transform our understanding of cancer and open the door to new and better ways to diagnose and treat the disease.

Mission critical

At the official opening of NPL in 1902, HRH the Prince of Wales quoted NPL's purpose as "to bring scientific knowledge to bear practically upon our everyday industrial and commercial life" and this mission may never have been more important than right now, in 2020.

As the UK went into lockdown, our scientists and engineers set to work applying metrology to some of the challenges presented by Covid-19. NPL worked on the development of reference virus-like particles exhibiting nanoscale properties and characteristics. This aids accurate, differential measurements of cells, viruses and virus-like structures in clinical samples. The comparison studies helped improve repeatability and reproducibility of proposed methods and materials, and validated measurement results with traceability to the SI system. This is fundamental to ensure the quality, approval and delivery of safe and effective vaccines.

During the pandemic we maintained our work in distributing the national timescale and radiation dosimetry for cancer therapy. Our scientists and engineers contributed to the ventilator challenge and also provided data analysis to the Royal College of General Practitioners Research and Surveillance Centre to help them produce their regular updates on communicable and respiratory diseases for Public Health England.

As the first lockdown eased, we noted how Covid-19 had so quickly changed the way we live our lives. Businesses were, and still are, recovering from periods of shutdown and reduced working hours. The pressures of working under new social distancing rules brought new challenges to 'normal' ways of working. And so, in August, supported by our colleagues in the Department for Business, Energy and Industrial Strategy, I was delighted to launch Measurement for Recovery (M4R), a programme in which we are supporting companies to innovate and address the many challenges businesses currently face – by matching them to world-leading metrologists in their fields and to the techniques and technologies only available at NPL and our partner laboratories.

One of the biggest changes we have faced is our new reliance on digital technology and its associated infrastructure. Most of the population will, during the past six months, have benefited at some point from working and socialising via Zoom and MS Teams or shopping via online retailers – for many, every waking minute seems to be spent in front of some sort of screen. This of course, presents new challenges: infrastructure and associated connectivity issues, cybersecurity and data processing and management.

From our original measurement infrastructure, built on physical foundations, we are now presented with a new type – a digital one. A metre is no longer a stick but is a laser wavelength, time no longer a pendulum but the ticking of an atom.

To this end, we are developing our digital infrastructure. To make sense of the ever-increasing range and quantity of data being generated, society is turning to artificial intelligence (AI) and algorithms to sort and interpret the data. It is essential that we are able to quality-assure our data and understand decision-making processes, especially for safety-critical applications. Discus-

Dr Pete Thompson FREng is CEO of the National Physical Laboratory (NPL). He took up his present role in September 2015 and has overseen the Laboratory's development and growth since its change in status to a public corporation. Prior to this he was a Board Member and Deputy Chief Executive at the Defence Science and Technology Laboratory (Dstl), responsible for corporate strategy, governance, strategic relationships, communications and human resources. In addition to being a Fellow of the Royal Academy of Engineering, he is the recipient of two MOD Chief Scientific Adviser Commendations and the US NIMUC award.

One of the biggest changes we have faced is our new reliance on digital technology and its associated infrastructure.

Most of the world's cybersecurity infrastructure is based on the exchange and use of digital cryptographic keys. We are looking to address the lack of authoritative certification of the unique randomness produced by quantum random number generators.

sions with industry and – at an international level –with other National Metrology Institutes have emphasised the need for internationally accepted and standardised infrastructure for the provenance of data.

We must also adopt FAIR principles. Data should be Findable, Accessible, Interoperable, and Reproducible, so that maximum value can be extracted. We are working with colleagues across the UK Quality Infrastructure to develop data quality frameworks that will be important across industry and the digital economy.

The UK's Measurement Strategy prioritises the ability to deliver confidence in the intelligent and effective use of data. This supports the UK's aspiration to be a world leader in the effective use of data, and is underpinned by a professionally equipped workforce, accredited to the highest standards. NPL is proud to be a world leader among National Metrology Institutes, developing standards for data science that will provide confidence in decision making, driven by collaboration with fellow Public Sector Research Establishments.

Developing skills

This new infrastructure also requires associated skillsets and we are working to develop the skills the UK will need. It is important that we are developing a digitally literate and technically skilled workforce that will be able to support the emergence of new sectors of industry and adapt as more established sectors undergo digital transformation. There will be an increasing need for people with data science skills and so there needs to be appropriate training and professional recognition in order to demonstrate that they meet required standards. NPL is working alongside the UK's Learned Societies and others to establish industry-wide professional standards for data science, to ensure an ethical and well-governed approach and give confidence in the professionals who are working with our data.

In its drive to be a scientific superpower, the UK is looking to create a quantum-enabled economy. Quantum technologies are an integral part of the UK's digital fabric and advanced manufacturing base and will add significant value to the UK's prosperity as well as its security.

Earlier this year, scientists from our Quantum Metrology Institute announced a major inter-disciplinary Industrial Strategy Challenge Fund (ISCF) project: Assurance of Quantum Random Number Generators. This is being led by NPL with key partners from the UK's leading developers of optical quantum random number generators (QRNGs) and UK universities.

This project confirmed that most of the world's cybersecurity infrastructure is based on the exchange and use of digital cryptographic keys. Random numbers are essential to this infrastructure and to new technologies such as quantum key distribution. Through this project we look to address the lack of authoritative certification of the unique randomness produced by QRNGs.

We have also been forging ahead with the National Timing Centre programme, which will develop the enhanced national time scale UTC(NPL) and will become the resilient source of timing for the UK. We launched this programme in 2019 because we were already aware that subtle changes were afoot within our digital infrastructure that needed our urgent attention.

Across all sectors we are hugely dependent on an invisible utility, one that guides our every waking moment – timing. It is an underpinning capability that is necessary for synchronisation in everything from telecoms and broadcast, through to traceable time stamping for regulatory compliance in the finance sector. Currently we depend on Global Navigation Satellite Systems (GNSS) for our global positioning, navigation and timing. Our reliance on these weak, space-based signals makes us vulnerable to jamming and spoofing, as laid out in the Government's Blackett Review[1].

Our vision is to increase the UK's resilience by leveraging multiple technologies, each with different failure modes and risks for time dissemination (including GNSS) to provide a resilient timing service for the digital future. As emerging applications such as autonomous vehicles, AI, distributed computing, smart cities and distributed ledger technologies go mainstream, we are ready to enable them.

As the pace of technological change accelerates, society needs to adapt in order to realise the full benefits and opportunities. We recently completed our Vision of the 2030s shaped by metrology; *Technology and Measurement Foresighting*[2], which highlighted the major trends in the future of society and industry and analysed which technologies will be vital to enable them. These trends are grouped according to impact area: built environment; energy; food production; healthcare; manufacturing; and transport.

Whether it is driving the green recovery or ensuring intelligent use of data with confidence, the UK's position as a science superpower depends on a measurement infrastructure which is well-equipped for our digital future. □

www.npl.co.uk/contact#

1. www.gov.uk/government/publications/satellite-derived-time-and-position-blackett-review
2. www.npl.co.uk/foresighting

Politicians should be able to make decisions aware of the best available evidence. However, concern is sometimes expressed that the difference between science advice and political decisions might be blurred. That distinction was examined at a meeting of the Foundation for Science and Technology on 15 July 2020.

Modelling as a route to understanding

Angela McLean

SUMMARY

- SPI-M models aspects of the pandemic and is a sub-group of SAGE
- Mathematical modelling is used to examine the potential impact of a range of complex interventions
- This helps to highlight those actions where there is a level of confidence and to identify areas where more information is still required
- Collaboration does not compromise independence
- Science advice can only be one factor in political decision-making.

I co-chair the Scientific Pandemic Influenza Group on Modelling (SPI-M), a group of mathematical modellers who form a sub-group of the Scientific Advisory Group for Emergencies (SAGE). We provide advice to SAGE; then Sir Patrick Vallance and Professor Chris Whitty, the Chairs of SAGE, take that advice to Ministers. The process can be complex, with a certain amount of to-and-fro between academics and civil servants.

We have been trying to identify a suitable set of questions – we call it the 'commission' – to which we can offer an equally sensible response from the academic modellers. When I first joined the process, the commission was a very long list of questions. When lockdown was imposed there were 10 interventions – from self-isolation when poorly, household quarantine when someone else was poorly, to the closing of playgrounds. So the first commission was, very nearly, to examine all the possible combinations of those 10 interventions.

After much discussion, backwards and forwards, we developed a much broader range of 'science advice products' that we took to SAGE. As an example, in one of these, we model the number of people venturing outside of their front door against the 'R' number that is talked about so much (the average number of secondary infections caused by one case). Then we include the proportion of primary children back at school. Add estimates for the effectiveness of contact tracing and our Covid security and we can get some projections on, the likely impact of different combinations of social distancing rules.

What we are trying to do with this modelling is to capture those aspects we feel secure about. Quite a lot is known about how different age groups in society mix with each other. We feel reasonably secure about (roughly) how many people are venturing outside of their front door. There are also things we do not know so well yet. For example, we are steadily getting a better understanding of the effectiveness of our contact tracing.

One of our concerns has been that somebody would take one of these 'snapshots' and use it to say 'oh, well I can let another 5% of people leave their homes today then', which is not what these are for. They certainly cannot predict exactly how big the R value is, but they do offer some understanding about how it changes with variation of the many different activities we could have more or less of. I believe that, with the discussions between civil servants and scientists in my circle, progress has been made.

Collaboration

There is certainly a feeling that we are achieving more useful answers – and the civil servants feel they are asking better questions. Collaboration is, after all, a two-way street.

That collaboration between different sorts of people has involved astonishing amounts of long hours worked. Because of that, we have been able, again and again, to respond quickly to questions from politicians and civil servants, providing timely, relevant and independent advice.

Collaboration makes some people feeling uneasy. How is it possible to collaborate with the

Professor Dame Angela McLean DBE FRS is Chief Scientific Adviser at the Ministry of Defence, a post she has held since 2019. In that role she provides strategic leadership for science and technology in the Department, sets strategic direction for S&T in Defence and oversees more than £350 million of annual research. Professor McLean has been a Professor in Mathematical Biology in the Department of Zoology at the University of Oxford since 1994 and is a Fellow of All Souls College. She was elected a Fellow of the Royal Society in 2009 and awarded a DBE in 2018.

Collaboration makes some people uneasy. How is it possible to collaborate with the people asking the question and still be independent?

It is common for people to say they are 'following the science'. I would be happier to talk about 'hearing' the science.

people asking the question and still be independent? I do not believe that is a problem. It is common for people to say they are 'following the science'. I would be happier to talk about 'hearing' the science. Science advice should be present at the beating heart of Government decision-making, but it is only one of the things that need to be taken into account.

Reflecting on the months attending SAGE and co-chairing SPI-M, nobody who has been involved in an emergency in which so many thousands have lost their lives could possibly feel wholly happy about it. Yet, the experience of working with SAGE and SPI-M has been collegiate, it has been collaborative, there has been an intense sense of urgency in the work we have done and I, for one, would not have missed it for the world.

It has been possible to bring relevant science advice, developed at great pace, right into the heart of political decision-making. The fact that this has been so high-profile is good for science, but it is still as important as ever to preserve the independence of people who do that work. It must also remain quite clear that science advice is just one of the considerations on the table when politicians make their decisions. □

Being open and transparent about science

David King

Professor Sir David King ScD FRS HonFREng is Chair of Independent SAGE. He is Emeritus Professor of Chemistry at the University of Cambridge, and Founder and Chair of the Centre for Climate Repair at the University. Professor King was the UK Government Chief Scientific Adviser between 2000 and 2007, the Foreign Secretary's Special Representative on Climate Change, 2013-2017, and Chair of Future Cities Catapult, 2012-2016. Professor King was elected a Fellow of the Royal Society in 1991 and knighted in 2003.

The principle of academic freedom in our universities entails that the primary character of their scientific research is that it is free from political interference. However, for a Government Chief Scientific Adviser (GCSA), who is appointed on the basis of being a world-leading expert in some field of research, the primary objective is to interact with the political system.

I spent 35 years of my career establishing my credentials in scientific capability. Then I went into Government to be a bridge between current science and the political system. The first Chief Scientific Adviser was Frederick Lindemann and his second in command was Solly Zuckerman, appointed during the Second World War at the request of Winston Churchill. Zuckerman gave advice on the conduct of the war, not just weapons or technology.

One key piece of advice was about bombing strategy in advance of the landing of the allied forces in France. Churchill had already decided there should be carpet bombing of cities and factories in Germany, but Zuckerman advised that there should be strategic bombing of railways and bridges so that German troops could not be switched across to where the landing occurred. This was direct advice and there was an argument with Churchill who, in the end, accepted that advice.

I believe that a science adviser in Government must advise on policies based on the best science. Of course, ultimately the politicians decide: the buck stops with the PM.

SUMMARY

- Government scientific advisers act as bridges between current science and the political system
- Advice to Government must be based on the best science available
- The adviser's role includes advising Government but also informing the public
- Scientific advice needs to be rigorous, accurate and jargon-free
- There is a great appetite for hearing expert views on issues.

The current official description of the role says: "The Government Chief Scientific Adviser advises the Prime Minister and the cabinet on science and technology policy issues which cut across individual Government Departments." That is a very clear statement and advising on policy issues is the key function.

I moved into Government shortly after the bovine spongiform encephalopathy (BSE) crisis in cattle which was a disaster for the British farming community. The Philips Commission published its report in the month that I was appointed Chief Scientific Adviser. What it said was, very clearly, that the GCSA and other Scientific Advisers must be able to put their advice to Government ministers and the Cabinet – but also into the public domain. That became my

mantra during my time in this role.

The reason for Phillips saying that was quite simple. During this epidemic among cattle, the Government Minister concerned tried to persuade the public that British beef was perfectly good to eat: he even fed his daughter a hamburger on television. This was at a time when it was understood that Variant CJD, a new human brain disease, probably arose from people eating British beef but science advisers were kept away from television. Phillips said, quite simply, "When they said they were following scientific advice, the people couldn't understand if that were true". So he concluded that science advisers must be able to go into the public domain with their advice.

That was my approach throughout the foot and mouth epidemic. When the Prime Minister at a COBRA meeting asked for advice, I was the only one who could provide guidance from a group of epidemiologists and veterinary scientists drawn from outside Government. I was subsequently asked to effectively take over the management of the epidemic and I set up a committee which included not only science advisers but also veterinary scientists, some from outside of Government. The Chief Veterinary Officer was a member and so, crucially, was a Ministry of Defence strategic expert who calculated MoD capability in military operations: this expertise was absolutely key to the management of the epidemic.

I met the Prime Minister once a day; he took decisions but always to back me and the decisions of the committee. Quite simply, as he wrote in his autobiography, he did not really understand the science underlying what we were doing and so he handed over to the scientists who could manage it.

Foresight

Subsequently, I turned the Government's Foresight Programme into an instrument of in-depth study. Each project involved at least 100 experts (the biggest had 350). It took two to three years to deliver an in-depth Foresight analysis with scenarios built forward in time. In one on flood and coastal defence issues, the scenarios went out to 2080, using available data on climate change and how flood risk would increase with rising sea levels.

When a report on climate change impacts went to Government, I was asked to present it to the Cabinet. The Prime Minister also asked me to talk to a meeting of parliamentarians about it. This was attended by members of both Houses of Parliament and led to the Government taking a leading role in global negotiations. The unilateral UK target of an 80% reduction by 2050 demonstrated how seriously we were taking the matter.

The Government Chief Scientific Adviser must be a good and clear communicator – language must be jargon-free, but be rigorous and accurate.

Another big programme focused on cognitive systems, looking at our capability in IT and brain science and bringing these two together. This was in 2001 to 2003 – in a way, it prefigured AI. What emerged from that work were a number of new university departments.

A key point about these programmes is that at least one Government Minister was brought into each programme. Of the four scenarios that we always predicted forward in time, one was very attractive and one not at all attractive, so Ministers were brought in to see what corrective action was necessary if we had started moving in the not so attractive direction.

The biggest project during my time with the Foresight Programme concerned infectious diseases. Indeed, it was that report, published by the Government Office for Science in 2006, that foresaw a pandemic of the kind that is now causing such damage.

Communication

The GCSA must be a good and clear communicator – language must be jargon-free, but be rigorous and accurate. I set up Independent SAGE because I was, frankly, worried that communication was not clear from the Government's Scientific Advisory Group for Emergencies (SAGE). We were not told any of their processes of decision-making, nor did we see the current Chief Scientific Adviser or Chief Medical Officer being made available to be challenged by the media.

When Independent SAGE was set up, it was not even public knowledge who was on Government SAGE. I want to stress that Independent SAGE is a group of experts who include a good group of healthcare specialists. We have experts on operational health. This means we can look right across the board and are able to give policy advice on that basis.

It is, in essence, an orchestra of specialists and I am simply the conductor. However, all members of the group take up frequent invitations to appear on television and radio and speak to the press. There is a very big appetite for experts to talk about the reality of the situation, what the policies are and what needs to be done. No one else fulfils this role of informing the public.

If we are to have an advisory system that has the trust of the Government, the Cabinet, the Prime Minister and also the public, then that is what we need. □

There is a very big appetite for experts to talk about the reality of the situation, what the policies are and what needs to be done. No one else fulfils this role of informing the public.

Advice and policy making in an emergency

Mark Walport

Professor Sir Mark Walport FRS HonFRSE FMedSci has recently stepped down from the post of Chief Executive of UK Research and Innovation (UKRI), overseeing the UK's research and innovation spending – a post he held since 2017. From 2013 to 2017, he was UK Government Chief Scientific Adviser. Before that, Sir Mark was Director of the Wellcome Trust from 2003 to 2013. He was knighted in 2009 for services to medical research and was elected a Fellow of the Royal Society in 2011.

SUMMARY

- Science, in its broadest sense, provides the evidence base for policy making
- Scientists advise but politicians decide – that is fundamental
- Modern, complex economies have become more efficient but also less resilient
- Policy makers constantly have to balance competing priorities
- Covid-19 is the most challenging emergency faced by a Chief Scientific Adviser in the past 50 years.

It is important to understand the relationship between science and politics in the broad sweep of national affairs, the role of science in an emergency such as Covid-19, and then its place in longer term issues such as climate change and environmental degradation.

It is also important to distinguish between the narrow view of science, the world of STEM (science, technology, engineering and mathematics) and a much more inclusive approach to scientific knowledge which I like to refer to as STEAM – science, technology, engineering, the arts and maths. That is what Germans call *Wissenschaft* and it encapsulates the broad sweep of knowledge resulting from systematic study and research, including subject areas such as human values. Looked at in that sense, science is the evidence base for politics and should be intrinsic to the political process.

George Russell, the Irish nationalist and polymath, wrote in 1912: "The great problem before democracy is the evolution of a social order which will ensure, so far as anything human can be ensured, that democracy will put forward its best thinkers, its wisest men of affairs and that it will develop a respect for the women of special and expert knowledge" (I changed one word in that paragraph!).

He continued: "Every people get the kind of politicians they deserve and we must organise the nation so that the people may be more deserving of – and more discerning of – better qualities in their public representatives than they are at present."

That was clearly a problem then and it remains a problem now, with no obvious solution in sight. In general, I think, with the rise of populist politics across the world, the application of Wissenschaft is in trouble.

Science in emergencies

The fundamental principle that governs the relationship between science and politics is that the scientist advises and the politician decides.

The topic of science and politics in emergencies is such a salient issue in the context of the Covid-19 pandemic. The fundamental point is that Government is supremely important in the leadership and policy decisions that need to be made at pace in the uncertainty of this global emergency. The fundamental principle that governs the relationship between science and politics is that the scientist advises and the politician decides.

When things go rapidly wrong there needs to be an established mechanism to bring science and politics together quickly. That is one of the strengths of the UK system, being one of the important lessons learned from the Foot and Mouth epidemic of 2001.

It is fair to say that not all the lessons of Iain Anderson's report in July 2002 have been learned. One lesson that was heeded led to the creation of the Science and Advice Group in Emergencies (SAGE). This was formed by Sir John Beddington in 2009 to help handle the Swine Flu pandemic and has operated regularly since then.

When things go wrong in a global emergency, there is a series of cascading consequences for complex, largely urban societies around the world. As modern economies have become more efficient, they have become less resilient, so a shock to one part of the system reverberates widely. The challenge is that policy makers constantly have to balance competing priorities – for example, maintaining the supply of goods and services while at the same time reducing the mobility of citizens as far as possible. Ultimately, it is for policy makers, who in democratic societies are elected politicians, to make the difficult decisions in the development and implementation of policies that take into account competing priorities.

Covid-19 is the most challenging emergency faced by a Chief Scientific Adviser over the past 50 years. The key goal must be to prevent direct harm from infection. However, policies aimed at

Scientific advisers join the Prime Minister at a No. 10 press briefing.

achieving this alone bring their own potential harms. There are other risks to physical health, from loss of access to health services to the impact on people with other diseases: so protecting the health service is a very important, strategic aim. There are risks to mental health from prolonged social isolation and being trapped in the home. Then there are the broader societal effects of the loss of education that a whole generation is facing, as well as the long-term risk to many millions around the world of changes in work patterns and opportunities. Looking to the future, there are huge issues of inter-generational equity – and these are just a few examples.

The policy maker looks through three lenses. The first is: 'What is known about this issue?' This is the lens of evidence. There is, however, often great uncertainty and this is where broad science advice is essential.

The second lens is: 'Is this policy deliverable, and what might be the consequences?'

The third lens that policy makers look through is: 'How does this policy fit with my own personal and political values, as well as the values of the electorate?'

Ultimately, politicians – the people we elect as our policy makers – integrate the inputs from these three lenses to decide on policies.

Too many commentators look through only one lens, taking an extremely narrow view, while policy makers have to look through all three. I have always thought it much easier to be the adviser than the decision maker.

Harold Laski wrote a coruscating letter to Oliver Wendell-Holmes in 1924, saying: "I can, I think, recite fairly fully on the habits of bureaucracy. The things which distinguish it are these: 1) Its members all say the same thing; 2) They cannot understand that their expert knowledge is open to independent enquiry [and here he was not referring to enquiry by other experts]; 3) They have complete contempt for all outside of their charmed circle; 4) They don't realise how many people there are who want a share, however small, in deciding their own destiny. They hardly see why people should want to make their own rules."

Keep experts in their place

There is a well-known aphorism which is often attributed to Churchill, but was actually by George Russell, who wrote in 1912: "Experts ought to be on tap, and not on top. The official classes will, I believe, be much happier serving the public than in setting snares or inventing schemes to control industries and movements they have no part in creating, where their interference would be fatal to any fine idealism or noble humanity."

Harold Laski, in that letter to Oliver Wendell-Holmes, echoed this, saying: "They cannot understand that their expert knowledge is open to independent enquiry. If I may so phrase it, they do not see that the business of an expert is to be on tap and not on top." □

When things go wrong in a global emergency, there is a series of consequences for complex, largely urban societies.

The debate

After the formal presentations, members of the audience were able to put questions to the speakers. Topics included: clarity of messaging; communicating uncertainty; trust and openness.

There was a concern that the public could become confused when Independent SAGE comes to a different conclusion from SAGE. On this point, there was some disagreement. One panel member pointed out that when Independent SAGE was originally set up, the minutes, advice and membership of SAGE were not being published, so there was no confusion. All members of Independent SAGE have been subject to scrutiny by the media. Independent SAGE at all times assessed the current position and gave advice on moving forward. For example, Independent SAGE was recommending action to head towards zero virus in the community. It was stated that the per capita incidence of Covid was very different in the different nations of the UK.

ARCTIC CIRCLE [CC BY 2.0] VIA FLICKR

Former Government Chief Scientific Adviser Sir David King established Independent SAGE.

The cost of zero virus

This was challenged by another panel member who said that, on the contrary, there was little difference between the four UK nations in per capita incidence of Covid. It was also argued that moving to zero virus in the community was policy advice not science advice (which should rather set out pros and cons of different options) and that moving to zero virus in the community would be extremely expensive.

Another panel member suggested that Independent SAGE had spent much of its time criticising the implementation of policy.

On the question of trust and openness, one panel member suggested that all advice and data from official SAGE should go into the public domain. However, politicians should have sight of that data for a while before it was made public.

In response to a question about the scientific knowledge of Parliamentarians, it was suggested that too few scientists and engineers stood for Parliament, but if scientists wanted to be involved in making policy, they should stand as politicians.

When talking to the public, it is important to strike a balance between having a clear message and communicating uncertainty. During the pandemic, the quality of science journalism has been very high, with journalists working extremely hard to report accurately.

The question of what will happen during the winter months is an example of an area of scientific uncertainty that must be well-communicated. Here it is important for scientists to speak directly to the public.

It was suggested by some of the audience that Ministers use science more for support than illumination. Scientific advisers stood next to the Prime Minister during some of the Number 10 press briefings on Covid and the wisdom of this was challenged. Some felt this left them too associated with the policy, not just the advice. However, such joint appearances had happened in the past (for example during the Novichok incident). Inevitably there were some risks associated with this and science advisers are certainly aware of them. However, the alternative would be to walk away and that seemed to be the wrong choice. □

FURTHER INFORMATION

Government Chief Scientific Advisers
www.gov.uk/government/groups/chief-scientific-advisers

Government Office for Science
www.gov.uk/government/organisations/government-office-for-science

Government Science Capability Review
www.gov.uk/government/publications/government-science-capability-review

Independent SAGE www.independentsage.org

Science Advisory Group for Emergencies (SAGE)
www.gov.uk/government/organisations/scientific-advisory-group-for-emergencies

The Covid-19 pandemic has already had noticeable effects on our environment, in terms of air quality and carbon emissions. But what changes in policy need to be made to make such benefits permanent? The issue was discussed at a meeting of the Foundation for Science and Technology on 27 May 2020.

The opportunity to protect the environment

Rob Jackson

SUMMARY

- Growth in energy demand is still outstripping the growth in renewable energy supply
- Covid-19 has resulted in a significant drop in carbon emissions
- Society need to make these declines in emissions permanent
- Covid-19 recovery funding could be invested in projects which work towards the UK's carbon-zero target
- Clean energy transition should be a core part of stimulus spending.

The Global Carbon Project integrates the work of hundreds of scientists who assess the state of global greenhouse gas emissions and concentrations, including carbon dioxide, methane and nitrous oxide. We monitor natural systems in the oceans and on land, and human activities such as agriculture and fossil fuel burning. We recently produced our first budgets for nitrous oxide and have also released our latest assessments for carbon dioxide and methane.

As background, the average global surface temperature has already risen 1.1˚C since pre-industrial times, we are well on our way to 1.5˚ and the past five years have been the warmest period on record. Global hunger and food insecurity are rising after years of welcome decline, so there is a lot happening due to climate change.

Why are emissions still rising? Despite the explosive growth in renewables of 14% per year over the past five years, oil and natural gas consumption are still rising. Only for coal, globally, is there a hint of decline at 1% per year. The reason is that energy demand, overall, is growing and is outpacing the growth of renewables. That really is the challenge to climate change – how to accelerate renewables and zero carbon technologies while stopping the continuing rise, even today, of fossil fuels.

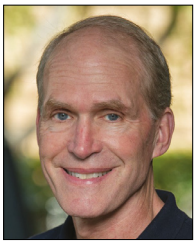
How has Covid-19 altered emissions? We looked at populations in different countries who were under lockdown or different levels of confinement. We also looked at estimates of activity. Surface transport reduced by half. Electricity consumption was down by about one-sixth or one-seventh. Manufacturing and steel production were down by a third. Aviation was down over 70%, although aviation is a substantially smaller proportion of greenhouse gas emissions than road transport.

Figure 1 shows carbon dioxide emissions over the past 50 years, in millions of tonnes of emissions per day. There has been a continuing rise. There were dips – the financial crisis had a very short 1.5% decline in 2009. Emissions shot back up by 5% in 2010, as if nothing had changed, so the world cannot rely on financial crises to reduce emissions. During Covid, though, during the peak reduction of activity due to confinement, there was a decline in emissions of 17%, although they are starting to move back up.

Drastic decrease

That is a huge decrease. In the USA, peak emissions decline was about one-third. Now that is an unsustainable decline in emissions: we do not want emissions to go down because there are hundreds of millions of people out of work and because we are locked in at home. Nonetheless, it has been a remarkable change.

Our estimate for 2020 is that US emissions will fall between 4-7%. The IEA suggests around 8%, which may not sound like a lot, but that is by far the biggest decrease since World War II, and maybe ever.

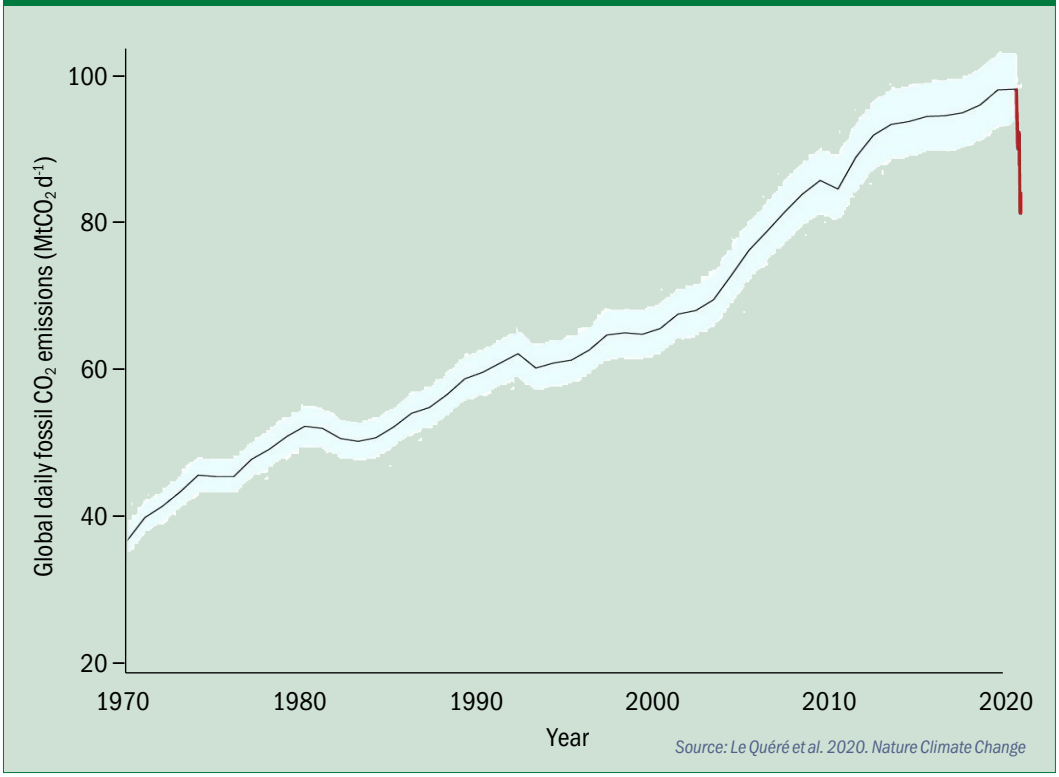


Professor Rob Jackson is Chair of the Global Carbon Project at Stanford University in the USA. He is the Douglas Provostial Professor of Energy and the Environment at Stanford University. His lab examines the many ways people affect the Earth, including the effects of climate change and droughts on forests and grasslands. A Guggenheim Fellow and current sabbatical visitor in the Center for Advanced Study in the Behavioral Sciences, he is also a Fellow of the American Association for the Advancement of Science, American Geophysical Union, and Ecological Society of America.

The financial crisis saw a 1.5% decline in 2009, but emissions shot back up in 2010. The world cannot rely on financial crises to reduce emissions.

In early April, global fossil CO_2 emissions decreased 17% compared to the same day of 2019. The global decline through April was 1.05 Mt CO_2.

Figure 1. Global daily fossil CO_2 emissions ($MtCO_2$)



Many countries show a similar decline in emissions: China, Europe, etc. In some though emissions are rising again. So how can we make declines more permanent? How can clean air and energy transition (which should be the goal in my opinion) be incentivised, with stimulus funding during Covid-19? Some 10 million people around the world work in renewable energy and many more in different aspects of energy conservation.

The USA

In the USA, there are $40 billion in low-interest loans currently sitting idle in the Department of Energy's Advanced Vehicles and Energy programmes. That is due primarily to politics. We should release that money so that people can go back to work and we can have progress. The big stimulus bill in Congress, the Health and Economic Recovery Omnibus Emergency Solutions (HEROES) Bill, does not include investments or production tax credits for wind and solar.

There are other opportunities and needs – providing comprehensive job re-training for people in the coal and fossil fuel industries, for example. The USA spent around $90 billion on stimulating renewable energy about 10 years ago and that had some of the best returns of any investment. The country is still reaping benefits today from the record low wholesale costs for wind and solar contracts.

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Around 100,000 people in the USA still die annually from car and coal pollution; globally the figure is more than one million people. By cleaning up our air, coupling that with the promotion of electric cars and such, we could have clean air every day without having to stay at home.

The UK

I am not an expert on UK policy, but it could invest Covid-19 recovery funds in technologies that would help the country reach its binding 'net zero' target. That would include decarbonising transport which has been the hardest sector to decarbonise. Building retrofits, energy efficiency, heating needs, low-carbon fuels, societal and personal choice, tree-planting – there are many possibilities.

The Committee on Climate Change has produced a set of recommendations which include investing to support economic recovery in jobs. Equity is a core principle for stimulus spending. Making sure the recovery does not lock in greenhouse gas emissions or increase climate risk is also vital. The EU and China are making clean energy transition a core part of their stimulus spending and their activities. The UK and the USA should do that, too. ❐

Doing right for the planet and for humanity

Kimberly Nicholas

SUMMARY

- Climate change is bad for people – both those alive today and future generations
- To hit a 1.5˚C warming target, emissions have to drop by half within 10 years
- Climate stability needs to be aligned with sustainable development
- Subsidies that harm the environment must be switched to actions that improve it
- There are many ways to achieve the change required: but we need to start today.

As this pandemic forces unexpected change on our daily lives, it begs the question of what life might be like on the other side of this crisis. What will a post-Covid world look like – perhaps even more importantly what could it look like? Will we take the opportunity to make real change?

There is overwhelming scientific agreement that the planet is warming due to human activity. Climate change is very bad for human beings, not just for future generations but for those of us living now. Most people alive today will see global temperatures rise by 1.5-2˚C. The present moment is really the last chance to stabilise the climate at a tolerable limit, and it is really urgent that we take it.

Sustainable development

We know from the Intergovernmental Panel on Climate Change (IPCC) that impacts will be much worse and more devastating if the world misses the 1.5˚C stabilisation target and reaches a warming of 2˚C or more. We need to reduce emissions by about 7.6% per year – that is the figure the United Nations Environment Programme (UNEP) says will be needed to achieve the 1.5˚C goal.

Globally, that means cutting emissions in half by 2030. Rich countries continue to have high emissions and must cut down more quickly. We need to focus all our efforts on making society compatible with a safe climate because the stakes are just too high to fail.

Yet to achieve this goal, not only climate targets but also sustainable development goals have to be taken into account. That means adopting principles of equity as well as managing land-use and other natural resources because biodiversity and nature also need room to thrive. We must determine what constitutes a good life for everyone within the biophysical limits this planet can afford and sustain.

Stabilising the climate means halting the emissions of carbon into the atmosphere entirely. Some of the carbon we currently emit stays in the climate for thousands of years so, essentially, to stabilise the climate those emissions have to drop to zero. As long as fossil energy is not completely replaced by clean energy, climate warming will continue.

To stabilise the climate, a system which is causing climate harm has to be replaced with one that is safe for the climate. As Leah Stokes from the University of California Santa Barbara points out, we do not just need 100% clean electricity, we need 200%, because we also have to electrify everything that uses energy, including transport systems which are now running on fossil fuels.

Agriculture

About a quarter of total warming comes from agriculture. The way people use land today is contributing to the climate problem. Humanity is degrading and destabilising ecosystems. This risks not only the stability of the climate but the very ability for life on earth to thrive. Nature has to be healthy in order to maintain a stable climate.

There is an opportunity at this point in time to shift from a system where a lot of money is invested in doing harm towards one that is sustainable, gives people good jobs and is compatible with the planet. At the moment, more than 6% of global GDP, some $5.2 trillion, is used to subsidise fossil fuels in order to make them cheaper, and to pay the social and health costs of the damages they cause. Continuing to build infrastructure for fossil fuels – pipelines, energy plants, etc – does not make sense and is incompatible with our remaining carbon budgets for a stabilised climate at 1.5˚.

Not only that, we need to shut down, ahead of schedule, some of these most-polluting infrastructure such as coal-fired power plants to meet agreed

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We have an opportunity to shift from a system where a lot of money is invested in doing harm towards one that is sustainable, gives people good jobs and is compatible with the planet.

JOÃO PIMENTEL FERREIRA/ (CC BY-SA 4.0)

The Hague, in the Netherlands, has a car-free city-centre, allowing residents and visitors to experience better air quality, less noise, and an improved quality of life.

warming limits. As we plan for economic recovery, we must keep these principles in mind. Money should be spent where it will do the most good.

However, this has to be a fair and just transition. Jobs are at the heart of this transition: health and wellbeing for people, communities and nature must guide our thinking on this.

It is not possible to go back to business as usual because that is a recipe for catastrophic climate change.

Achieving change

There are many ways to achieve the step change that is needed. First, change the incentive structure: we cannot keep investing in fossil fuels or other unsustainable technologies. Regulations and standards are important and have historically played a significant role in the limited progress to date in reducing emissions.

A new study led by Charlie Wilson at the University of East Anglia, reported in *Science*, showed that one of the most effective principles to inform post-Covid economic recovery will be small-scale transition or 'tiny tech': neighbourhood-based or locally-based incentives; training armies of workers to retrofit housing with low-carbon technologies; using local and decentralised forms of energy – and all the while taking advantage of the jobs and learning that brings.

There is a really historic opportunity here to better align what is good for the planet with what is good for the people: we must take it.

Transport is another area needing attention. Everywhere that we can, we should be looking to reduce car usage: they are a major source of emissions. Cities should be built for and around people, rather than cars. In cities around the world, people are taking back streets, away from cars, and are really appreciating being able to get exercise, move freely, get better air quality on foot or bicycle. These are healthy and effective ways of both reducing emissions and improving health.

Some industries are not on track to meet climate goals and do not have a plan to reduce their emissions. These need make a serious effort to lower emissions and that means lowering demand, actually – not planning for growth but planning ways to reduce and limit high-carbon activities in line with our remaining carbon budget.

There is a really historic opportunity here to better align what is good for the planet with what is good for the people: we must take it. □

Addressing the issues of climate change and biodiversity loss

Stephanie Wray

SUMMARY

- 'Getting back to normal' after Covid is not the answer to biodiversity loss and climate change
- It is not too late to restore our natural capital but we have to start now
- Climate change and biodiversity loss are interlinked
- Ecology needs to be at the centre of policy making
- Ecosystems need to be supported through a natural capital infrastructure plan.

In early March this year, I am not sure anyone envisaged the extent to which all of our home and working lives were about to change due to the Coronavirus pandemic. There is now a great deal of talk about 'getting back to normal' as soon as possible but frankly, from the perspective of restoring biodiversity, getting back to business as usual is the last thing that we want. Let's leave the old way of doing things behind and instead consider some of the changes required in the brave new post-Covid-19 world.

There had been an expectation that 2020 would be a moment for biodiversity and nature – global meetings, a world conservation congress, UN oceans conference, a UN nature summit – that was all to culminate in Kunming in China, in the Global Biodiversity Conference. This would agree on a game-changing, post-2020 global biodiversity framework. This was supposed to be the year that launched a decade of restoration and put nature-based solutions front and centre of climate negotiations.

The imperative to act now

It is not too late to make a difference to biodiversity, to natural capital, to nature, but only if we start now. Delays to these international meetings are not helpful, because change is needed at every level, from local to global. The 2019 report from the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) said: "Through transformative change, nature can still be conserved, restored and used sustainably." Transformative change means fundamental, system-wide reorganisation across technology, economic and social factors, including society, paradigms, goals and values – steering right away from the current paradigm of economic growth at all costs.

There have been some apparent benefits to the natural environment during the Covid-19 lockdown. There is good data to show some marine, freshwater and terrestrial species which are evidently thriving in the absence of noise, light and direct disturbances. We read that wild flowers are thriving on our road verges because the amount of maintenance and routine management has gone down. Sensitive habitats like flora and ancient woodland will be benefitting from improvements in local air quality. My social media feeds are full of people interacting with and appreciating nature. That is important – if you do not appreciate nature, you will not want to save it.

Yet it is not all sunshine and roses. While most of the law-abiding citizens of the world, and most of the law-enforcers, have been in some degree of lockdown, this has provided an opportunity for illegal logging, poaching of particularly high-value items like ivory, as well as hunting, over-fishing and over-exploitation of other wildlife. At the moment, fish prices are high, so it is a tempting time for people to indulge in taking more than a sustainable proportion of that resource.

The UK has seen an increase in waste and fly-tipping because the recycling centres have been closed. There is an increase in food waste because supply chains have struggled to adapt to sudden change with everyone eating at home now. There has been a surge in single-use surgical masks.

Looking forward, how can we use what we have learned about environmental benefits and risks associated with sharp drops in economic activity to better understand the mechanics of environmental sustainability? How can we avoid rushing back into the flight path of disaster when the pandemic loosens its hold? It is surely time to create policies that recognise we need to have clean air to breathe and water to drink.

We can take some lessons from communications around Covid-19: how to explain in human terms why it is necessary to take difficult actions in pursuit of a more important, strategic outcome.

Dr Stephanie Wray is an ecologist and the Managing Director of RSK Biocensus, an environmental consultancy specialising in biodiversity and natural capital issues. She is a former President of the Chartered Institute of Ecology and Environmental Management, and is the Chair of the Institute's Strategic Policy Panel. Her work focusses on environmental law and policy, sustainability and biodiversity; she advises both Governmental and private clients.

The UK has seen an increase in waste and fly-tipping because the recycling centres have been closed. There is an increase in food waste because supply chains have struggled to adapt to sudden change with everyone eating at home now.

Ecology is often misunderstood and quietly left to one side. In reality, it needs to be at the centre of things.

Prioritising important strategic outcomes over immediate wants is not something that human brains are generally very good at.

What should happen now? First, it is really important to understand the interdependencies between climate change and biodiversity loss; after all, the outcomes of both are closely linked. Ecology is often misunderstood and quietly left to one side. In reality, it needs to be at the centre of things. How we interact with the environment is important in all policy making. We should be testing out policy decisions in tax, in transport, in healthcare, against their impact on nature.

Biodiversity assessment should be mainstreamed across all land-use decisions. There should be a natural infrastructure plan – how will we support the ecosystems that support us? Our global food system, for example, is vulnerable to biodiversity loss: if we lose pollinators, we lose 35% of our global crops. Of the million species at risk of extinction, we need to shore-up those natural ecosystems and invest in things like agro-forestry, regenerative agriculture and mangrove restoration.

Targets should be set for the protection of much larger areas if we are really to preserve ecosystems structurally and functionally. Ultimately, the aim should be to place 30% of land and sea areas under conservation measures with 10% strictly protected.

Reporting on biodiversity and ecosystem services should be mandatory for companies alongside their climate reporting. If the wider effects on biodiversity are not included, you have not really understood the issue about carbon emissions.

Finally, we should think about economics as though the environment matters. If Amsterdam can do it, other cities – and indeed policy makers – can. While the twin crises of biodiversity loss and climate change may seem more nebulous than Covid-19, they are much more threatening. ❐

Revisiting and strengthening the targets agreed in Paris

Peter Betts

Peter Betts has a wide range of roles including Strategic Advisor at Willis Towers Watson; Senior Fellow at the European Climate Foundation; Expert Adviser to the UK Climate Change Committee; Senior Advisor to the Director-General of the International Renewable Energy Agency; and Visiting Professor of Practice at the LSE Grantham School. Previously, he was Director, International Climate and Energy, in the Department for Business Energy and Industrial Strategy (BEIS), where he coordinated overall UK policy on international energy and climate change, including the UNFCCC negotiations.

SUMMARY

- The Glasgow climate conference in 2021 will be an opportunity to revisit Nationally-Determined Contributions (NDCs)
- The NDCs agreed in Paris in 2015 will only reduce emissions by around a third of that needed to stabilise climate with 2 ˚ of warming
- The UK Presidency will be looking to get countries to raise the level of their NDCs
- The rescheduled conference will now be well after the US elections which may offer time to change the geopolitics, at least on climate
- The UK will have to lead by example and prioritise climate in its diplomatic engagement.

The UK has been chosen to host the next major climate meeting, which was to have been at the end of this year in Glasgow but will now be at the end of 2021. It was inevitable, given Covid, that it would be delayed.

Glasgow will be different from the big Paris Agreement of 2015. Paris negotiated a treaty, whereas there is comparatively little to negotiate in Glasgow. Alongside the Paris Agreement, there were commitments from countries to reduce their emissions. These were called 'Nationally-Determined Contributions'. These were significant and would reduce emissions by about a third of what was needed to stay on track for 2˚C global warming, but that left a big gap.

Paris also provided for these targets to be revisited every five years. Glasgow is the first of these opportunities. Revisions of NDCs will probably happen not in Glasgow itself, but in national capitals before the conference opens.

In the absence of action by countries around the world, emissions might reach about 64 gigatonnes of CO_2 by 2030. To be on track for 2˚ the world should – according to UNEP - be emitting around about 41Gt in 2030, while to be on track for 1.5˚ that figure drops to about 24Gt. The NDCs adopted at the time of the Paris Agreement, though, will only take us to about 54Gt.

So, essentially, Glasgow, to get on track for 2˚, would have to agree further emissions reductions of 13-15 billion tonnes (25% against current levels), while to be on track for 1.5˚ the figure would be 30 billion tonnes. Yet countries do not see climate change as a first order issue, even though

the EU and the UK are increasingly very ambitious. So the likelihood of getting increased overall reductions on this scale at this conference are small.

Back-of-the-envelope calculations suggested pre-Covid that the very best that might be politically feasible could be about a 6Gt reduction, not enough to bring us on track for temperature goals. Of that figure, around half might come from China. Virtually all of the world's growth in emissions is coming from emerging economies and developing countries, so we have to persuade them to engage.

Pre-Covid, the UK Government already understood how challenging the ambition gap was. The geopolitics were bad and much worse than they were in Paris, which was a uniquely benign set of circumstances in 2015. There were also issues for the COP Presidency: the UK has other major priorities such as Brexit, and climate was not on global leaders' minds, even before Covid.

The first priority of the UK Presidency in its COP strategy pre-Covid was as much ambition on country pledges as possible, obviously. This would be in the form not only of higher ambition for 2030 through NDCs, but through ambitious long term goals to reach net zero emissions.

The second was to drive bottom-up change in the real world and the economy which can take us further. There a risk of greenwash here, but there is also great potential: renewable energy, on a levellised cost basis, is cheaper than coal in most parts of the world. Coal persists often for political/economy reasons, not because it is actually more cost-effective. Electric vehicles will soon, if not already, be cheaper than internal combustion engines. The UK would look to accelerate and build on these trends. There would also be a major focus led by Mark Carney on incorporating climate risks into investment decisions.

The third thing that the UK wanted to do was to rally the world around a narrative, and to build on the signals of higher NDCs and real economy progress to continue to signal that the trend towards a low carbon economy is irreversible.

Covid and beyond

Inevitably, Covid has soaked up the political oxygen in most countries of the world, with a risk that climate would be pushed down the agenda. The strategy retains the elements above but needs to take account of this political reality.

As we come out of the worst of this crisis, we are going to need fiscal stimulus packages to get the economy moving again. These must be climate-smart and sustainable. The EU has made a start with the Green Deal. That is only the EU budget, and some Member States have also had green stimulus programmes though there have been risks in Europe as elsewhere that Governments protect high carbon incumbents like the automotive and aviation industries.

The European Green Deal is a set of policy initiatives by the European Commission which aim to make the EU climate neutral in 2050.

Covid has stimulated behavioural change but will such changes be permanent? Will people go back to travelling or will they continue to use video conferencing? That could have a long-term effect on emissions.

Perhaps the experience of Covid will help us understand that preparing for big risks, particularly those we know are coming (like climate change) is essential. It would have been massively cheaper for us to have prepared for Coronavirus had we known it was coming.

The geopolitical situation is not good and Covid has accentuated the strains: the relationship between China and the USA, for example, (whether Trump or Biden wins) is much more adversarial than it was a few years ago, and the same is true to a lesser extent between the EU and China. Perhaps climate can become an area of shared interest where countries can cooperate; on biodiversity as well.

It was inevitable for public health reasons that the conference would have to be postponed, but that means it is pushed back well beyond the US election; this offers an opportunity to change the political mood, particularly if the extra time could be used to reach an understanding on climate between a Biden-led USA and China.

Finally, the expectations on the UK are going to be very high. The Government will have to raise its own NDC target for example and increase its climate finance. And it will need to be highly active in convening, while using its diplomatic capital to lead the global debate on climate. ❐

Applying evidence to policy

Gideon Henderson

Professor Gideon Henderson FRS became Defra's Chief Scientific Adviser in October 2019 and is a Professor of Earth Sciences at the Department of Earth Sciences, University of Oxford. He is also a Senior Research Fellow at University College Oxford, and an Adjunct Associate Research Scientist at the Lamont Doherty Earth Observatory of Columbia University. In 2013, he was elected a Fellow of the Royal Society. His research uses geochemistry to understand surface earth processes, particularly those relating to climate, the ocean, and the carbon cycle.

SUMMARY

- Changes in human behaviour from the pandemic have helped us understand more about the way humans react with the environment
- Air quality is one area where interactions between the environment and human health become apparent
- The risk of zoonosis is increasing due to environmental degradation
- The link between human health and a healthy environment is becoming ever clearer
- There is a recognition that climate change and biodiversity loss are even bigger challenges than Covid and will require long-term action.

Humanity has, in effect, been running a series of experiments on our planet and the data is there to learn from what we have been doing. The Covid outbreak has led to a huge change in behaviour. This has, for example, resulted in changes to carbon emissions and air quality. We can see what the impact of a dramatic reduction in road traffic on air quality can be, particularly for us in Europe.

When we look at the data for one of the pollutants, nitrous oxide, there has been a substantial reduction as a consequence of lower transport use and other changes. That has not been the case for all pollutants. One of the others, fine particulate material – PM2.5 – has, at least in the UK, remained remarkably constant. So there is an opportunity here to learn from this experiment that we have run on our planet about the relationship between air quality and our transport needs. It is likely that PM2.5 is controlled by a diversity of factors in addition to car transport. That understanding can help to inform policy and is one of the things that the Department for Transport is looking at in the UK. There is a sense that we can learn from this process and there will not be a straightforward return to the old world of pre-Covid.

So that is one experiment. Our impact on biodiversity and the consequent changes in nature is another – there is a great deal to learn and to bring into our policy-making from these.

Covid has also pointed to a relationship between our environment and our health. There are several strands to this, one of which is air quality. It is clear now, through evidence from other countries as well as the UK, that there is a relationship between the chances of dying of Covid and the air quality in the area where a person lives. This is very likely driven by the fact that bad air quality leads to a number of health complications and risks, leading to those 'underlying health conditions' that people hear about on the news associated with individuals who have died of Covid.

It is clear now, through evidence from other countries as well as the UK, that there is a relationship between the chances of dying of Covid and the air quality in the area where a person lives.

So there is an increased recognition, from this disease, that there are health implications from living in a bad environment and living with bad air. That is reinforcing the conviction that we must clean up this and many other aspects of our environment.

Another recognition that has grown significantly over the past months is that the risk of zoonosis – where a disease jumps from animal to human – is probably increasing because of the environmental degradation that we have caused to our planet. Deforestation in particular is leading to closer interactions between humans and wildlife. This in turn is leading to greater zoonotic risk both now and in the future. That should therefore strengthen our motivation to steward our environment better.

There is an associated relationship with climate – if the climate warms, the risk of zoonosis increases. This particularly the case for vector-borne diseases like Zika and West Nile, which are being transported to higher latitudes, including the UK, as we expect a warmer climate into the future. That is another reason why we should care about controlling climate.

While those are two negative reasons why we should care more about our health now because of Covid, there is also a positive outcome. People have really recognised how much they enjoy being out in the environment and seeing green things around them. There is already strong evidence of an explicit link between both physical and mental health and a person's access to the environment. There is a strong statistical anti-correlation between anti-depressant use and green space – people use fewer anti-depressants if they are exposed to green space in their life. This recognition has been dramatically enhanced during the current pandemic and we can use that to drive new policy directions.

Lessons for food and food supply are really

quite difficult to tease apart. Food supplies are clearly vulnerable because of the Covid outbreak. One response would be to grow more food and for individual nations to be more self-sufficient. However, that response would lead to land-use pressure if we are trying to grow more trees for our environment and grow more food at the same time – we will have a competition between those two.

Another approach might follow from a recognition that we are not growing our food efficiently – we could make it more efficiently and have a more efficient system. Why are we still picking our fruit and vegetables in fields with migrant labourers rather than in factories or in vertical farms with robots? We can investigate different ways to produce food and we may be able better to control greenhouse gas and environmental damage through food production choices in the future.

The recognition of the food supply challenge will create some policy drivers that are currently quite hard to predict and it will be interesting to see how the resultant policies interact with the environment.

I believe there is a very strong sense in Government that the country should not go back to the 'old normal'. There is a desire to see what can be learned from lockdown and the process of dealing with the Covid response. There is also a wish to see a green dimension to the recovery.

In addition, there is widespread recognition that climate and biodiversity loss are bigger challenges than Covid, they just happen more slowly and need more long-term action than the more immediate action that is being applied to counter the pandemic. ❐

Climate and biodiversity loss are bigger challenges than Covid, they just happen more slowly and need more long-term action.

The debate

The pandemic has led to significant behavioural change, and evidence suggests that some of this may last beyond the pandemic. Behavioural change alone is not sufficient: it must be combined with Government action. Countries may have different priorities – some developing countries will want to see more aircraft flying.

Prior to this year, global emergencies such as a pandemic seemed very distant to people – now that the possibility is apparent, they may think about the environment in a similar way. If the public's view of science had been enhanced by the crisis, it may be easier to communicate what the science says is needed to tackle climate change.

The Covid crisis can provide a stimulus for a green recovery, but climate change needs to be tackled internationally. Action is needed now. In some places where national governments are not acting, sub-national authorities are stepping up.

The assumption that flying will steadily increase should be challenged: some countries such as Sweden have seen a cultural move away from flying. Scientific conferences are the primary reason why university staff fly. Conferences have gone online because of Covid. If that continues, a significant reduction in university emissions can be achieved.

The lack of global coordination in the Covid crisis has parallels for tackling climate change. Better international action would have been better for Covid. Countries have tackled the pandemic separately, but that will not be possible with climate. Unlike Covid, climate action does have a global process; the question is whether it is strong enough to tackle the problem effectively.

Reuse and recycling were discussed, the supply and disposal of Personal Protective Equipment (PPE) during Covid was a particular example. Moves towards a circular economy will be important, but the right incentives need to be put in place.

Will democratic governments take such draconian measures for climate as for Covid? Democracies need to step up now and take action before such drastic steps are needed. Democracies can intervene in capitalist systems to promote the changes they want. If the right incentives are put in place, people and companies can be profitable by driving technologies and activities in the right direction. ❐

After the presentations, members of the audience raised issue including: similarities between different crises; behaviour change; international coordination; and the benefits of early action.

FURTHER INFORMATION

Fossil Fuel Subsidies Remain Large: An Update. International Monetary Fund www.imf.org/en/Publications/WP/Issues/2019/05/02/Global-Fossil-Fuel-Subsidies-Remain-Large-An-Update-Based-on-Country-Level-Estimates-46509

Temporary reduction in daily global CO_2 emissions during the COVID-19 forced confinement. *Nature* www.nature.com/articles/s41558-020-0797-x

Cleaning up the Electricity System. *Democracy* https://democracyjournal.org/magazine/56/cleaning-up-the-electricity-system

Tiny Tech Needed for Rapid Progress Towards Emissions Targets (2020) *Science* www.aaas.org/news/tiny-tech-needed-rapid-progress-towards-emissions-targets

Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target. *Nature* www.nature.com/articles/s41586-019-1364-3

A meeting of the Foundation for Science and Technology on 22 June 2020 looked at how UK businesses may emerge from the coronavirus, with a particular focus on how global supply chains might be different.

Creating agile, robust and responsive supply chains

Juliette White

Juliette White is VP for Global External Sourcing in AstraZeneca. Since joining the company in 1990, after graduating with a degree in Psychology, she has held a wide number of HR roles both in UK and US, including a period of time in a supply chain role within Operations. Juliette returned to HR in 2008 where she headed up the Global HR service centres, before joining Operations in 2010 as HR VP. She took over the role of VP of Global External Sourcing in 2014.

SUMMARY

- Supply chains provide strategic opportunities for businesses and national economies
- Lessons from the Covid pandemic can be applied to other challenges to supply chain operation
- Ensuring that supply chains can withstand disruption, even at a global scale, is critically important
- Global businesses cannot be over-reliant on one territory and need the ability to transfer to other parts of the chain in other territories when necessary
- The UK has several good examples of Government and industry working together to make supply chains more resilient.

Supply chains can provide a genuine commercial advantage, for a company and also for a country. Viewing supply chains as a strategic opportunity, not taps to turn on and off, means being able to leverage more and better healthcare. More broadly, the same applies to the economy.

Within the UK, as a life sciences company, AstraZeneca sees the full product lifecycle from end to end: from the true innovative discovery, through development manufacturing and then commercial manufacturing to, ultimately, the effect on the patient. We employ about 8,500 people in the UK, but there is also significant value creation in jobs that occur as a result of our presence in the UK and from the life sciences sector more generally. AstraZeneca is a significant investor in R&D.

Internationally, we have 26 sites in 16 countries and a very extensive external network that constitutes an agile, robust and responsive supply chain. Together, that results in about 25 billion tablets annually and about 1.4 billion finished packs, all of which ultimately pass through to patients. Our external network ensures that while we are present in a number of countries, but not over-dependent on one location or one economy.

Ability to deliver

Over the past few months, Covid has really illustrated that there is nothing more important than the ability to supply life-changing medicines to patients. Every single one of us who takes a drug believes it will do what it says and, importantly, that it will be there when we need it. So ensuring that supply chains can withstand and tolerate interruption at a global scale, as we have seen during Covid, is absolutely critical.

Covid has shown that there is nothing more important than the ability to supply life-changing medicines to patients.

The manufacturing of pharmaceutical products has been one of the most resilient supply chains in recent times and while there is always a level of stockpiling and inventory-building, what we have needed most is a supply chain that has been fast and responsive. We have seen surges in patient demands and needs, but also – quite rightly and properly – countries want to create an additional level of inventory to ensure that patient demand can be met by medicines on a continuous basis.

The planning that we did for Brexit has helped us, in three fundamental ways. It has helped us build additional resilience into the supply chain. We stress-tested our supply chains to determine where the weakest link was and whether that related to an internal or external asset. We reviewed all our inventory levels and subsequently created more of a buffer to make sure that we could continue to protect patients. Importantly, we have looked at new routes for despatching medicines. We came to call on these again as the Covid crisis hit.

Looking to a new normal

As we emerge from that Covid crisis, we need to look for our 'new normal'. The pharmaceutical industry has worked extensively with the UK Government and the NHS in order to tap into the global supply chain, sourcing materials that

might be in short supply in one location, pulling them in from another.

Looking forward, we need to ensure we have a really strong and vibrant life science sector in the UK and one that is underpinned by strong and secure supply chains. That needs to involve a sensible blend of onshoring while also recognising that we are a global business and part of a global industry. Our global supply chains must be resilient against future pandemics, or indeed any other large-scale business interruptions.

So as a business we cannot be over-reliant on any one territory. In simple terms, we need to make sure we have a complex network which can respond when events occur in one location which necessitate a transfer to another. It means dual-sourcing many key products to eliminate single points of failure. It means ensuring that the sourcing strategy carries additional and proper levels of inventory, that it has resilience built into it and that it has the ability to switch production from one source to another.

Our global supply chains must be resilient against future pandemics, or indeed any other large-scale business interruptions.

Cutting edge medicines and cutting edge device manufacturing make for a great domestic capability in the UK, but it is a capability that will not be just for patients here, it is a capability that creates extraordinary export capability as well.

AstraZeneca will continue to work with all parties to identify gaps in the supply chain and work responsibly to eliminate them. There are examples of cutting edge capability in the UK, whether it is the Medicines Manufacturing Innovation Centre (MMIC) in Glasgow, or the Vaccines Manufacturing and Innovation Centre (VMIC) in Oxford. Those are really good examples of where industry and Government can work in partnership to build great innovation and resilience within the UK, for the UK, while also creating real value that can be exported on behalf of the UK. □

The priorities for the post-Covid supply chain

Lenny Koh

Professor Lenny Koh is the Founder and Director of the Advanced Resource Efficiency Centre, and the Head of Communication, Partnership and Internationalisation of the Energy Institute, at the University of Sheffield. Her work focusses on advancing the understanding and resolution of complex supply chains using interdisciplinary approaches crossing supply chain management and information systems domains. This is designed to move supply chains towards resource sustainability.

SUMMARY

- Most countries have suffered a loss in economic activity in 2020 but are forecast to return to growth in 2021
- There are lessons to be learned from the experience of Covid-19 as we look to build a new, more resilient supply chain structure for the future
- Social, environmental and economic capital are all important in planning the supply chain of the future
- We will need to prioritise the international partnerships we want to build upon
- In the post-Covid-19 world, the key challenge will be to achieve more collaboration and expansion with the global supply chain.

The Covid-19 pandemic, which has forced industry to adapt and respond, has been an eye-opening experience for different types of supply chain. The future supply chain in the UK will need to optimise stability, security, sustainability and resilience in order to prepare for the recovery.

Most economies in the world are experiencing negative growth this year, except China. Covid-19 has made a major disruption to the whole supply chain. The US economy is expected to contract by 6.5% this year, but next year it will rebound back to 5% growth. The Chinese growth for this year is 1% but next year it will go back to 8%. The UK situation for next year is 6%, which is actually a very positive number, but for this year it is set to see a drop of 8.3%. Looking at the EU, economic activity is forecast to drop by 7.5% and next year it is only expected to grow by 6%. So, the UK and European economies will have similar performance.

Planning for recovery

There are many examples of the way businesses have adapted operations and supply chains have responded to the sudden increase in demand for products like masks, ventilators and others during the crisis. There already exists a level of resilience in our supply chain to respond to

Supply chains have responded to the sudden increase in demand for products such as masks during the crisis.

increased need. The question is whether this can become the norm? Can businesses learn from Covid and respond better, thereby minimising disruption and impact?

Although there are positive signs, there are also some lessons to learn. The supply chain has experienced fragmentation and shortages of certain key items. This is usually caused by inefficient resource management and inventory management in a global supply chain, where firms have had to rely on imports. When disruptions occur in these situations, they have a knock-on effect across the supply chain. Without a strong and resilient supply chain and without knowing the critical points in our own supply chain, it is very difficult to plan ahead.

Prioritisation

To plan for the recovery in the UK economy, it is crucial to understand the critical aspects of the supply chain. It is important then to link this to the green economy if we are to achieve a sustainable future. Social capital, environmental capital and economic capital are all important: without capturing all three dimensions, it will be very difficult to create a viable plan for a green recovery.

Critical resources and sectors include: materials and manufacturing; energy; food; digital; telecom; transport; pharma and medical. Based on recent experience, many of these sectors and supply chains interact, both within the UK and internationally.

The UK is currently a net-importer: there was a net export deficit of $220 billion in 2019. So there is a great opportunity, from this point onwards, to focus on increasing export capabilities in different sectors.

The UK has trading partnerships with many countries but as we plan for the future we will need to come to a consensus about the international partnerships and the key sectors we want to prioritise, especially where we have identified critical resources in the supply chain.

In the post-Covid-19 world, the key challenge will be to achieve more collaboration and expansion with the global supply chain, rather than retraction, so that the economy bounces back. Then it will be important to involve more SMEs going forward.

There are a number of specific features that we may see in the UK supply chain of the future. It is important to keep expanding the global links, while recognising that in having a global supply chain a multi-lateral approach will increase its security, stability, sustainability and resilience. That will also result in a better economic environment and impact, as well as having favourable social and environmental impacts.

A purely national-level supply chain will have a similar structure, but it will tend to have lower economic impact as a result of lack of access to the global economy. It would, nevertheless, have more local environmental and social impacts, leading to a positive influence on net zero targets.

Moving forward, a future supply chain that is more global, one that will optimise environmental, economic and social impacts, will be a win/win situation for all parties. ❐

The importance of resilience

John Loughhead

SUMMARY

- Covid-19 has resulted in an increased focus on the resilience of supply chains
- The trade-off between resilience, efficiency and cost is being re-evaluated by many organisations
- Levelling up will create new opportunities as resources are re-distributed
- Standards are important and can be used to increase resilience
- The introduction of new technology will enable us to increase resilience in supply chains.

The UK has, for a number of years, run a very open economy and as a result we have enjoyed the benefits of a very efficient, 'just in time' method of supply for much of our economic activity. This has been optimised on operating cost and economic cost. The crisis of the past months has demonstrated certain shortcomings of this system in terms of its resilience in these difficult times.

We have seen quite clearly the increased recognition by many companies and organisations of the importance of resilience in their supply chains, particularly when faced with unexpected situations. There is a need to consider more carefully operating practices and processes as a way of seeing what might be done to increase that resilience.

This can be achieved in a number of ways. Some of the responses have involved re-assessing the nature of the supply chain itself, and the criticality of the products, services or inputs that it deals with. There is quite clearly a trade-off between resilience, efficiency and cost. As we emerge from this crisis and move into a new way of operating, one of the things we will see is an increased dialogue about the extent to which we are prepared to make those trade-offs in order to improve future efficiency.

The nature and resilience of the UK's infrastructure is critical in determining the nature of the supply chains it will operate. This is not just about the physical infrastructure of ports, roads, railways and air traffic, but also the digital infrastructure that we are increasingly using.

The experience of the past few months has advanced our application of digital technology, probably in a way that would otherwise have taken years to come about. One of the implications is that we have seen, very clearly, a dramatic growth in e-commerce in the way we manage our economy. That, as we go forward, will significantly touch on the nature of our post-Covid business, because the development, adaptation and acceptation of that approach will squeeze some of the retail businesses that we are accustomed to using and the way they have exploited their physical presence on the high street.

Among the declared objectives of the current Government are net zero goals for our emissions and the process of levelling up economic activity in the regions. By definition, levelling up will mean a different distribution of resources which, of itself, gives greater opportunities for regional capability in supply: this should help resilience.

Of course, regional disparities are generational in nature. They have not occurred overnight and it will be impossible to change them immediately, but the basis of what needs to be done in order to improve productivity and growth has not changed.

We have witnessed, quite clearly, the enormous flexibility and adaptability that companies operating within the UK have shown within their existing processes, during the difficulties of the pandemic. That has shown the value that can be achieved by doing things in a different way. We have seen, for instance, additive manufacturing being applied at much greater scale, enabling organisations to move into very different areas in a rapid and agile way.

A green recovery, which will inevitably involve doing many processes in a different way, will offer an opportunity for changes in systems that could, themselves, be made more resilient.

Standards are important in all supply chains and we saw, during the search to supply PPE, that some of the equipment sourced, although described in a particular way, proved not to be suitable for the standards required in a UK environment. Looking forward to potentially driving different international standards in a different kind of supply chain (operating internationally as well as nationally) there is an opportunity to think about how those standards can be developed in such a way as to help improve the resilience of the process.

As an engineer, I believe that as we go forward with a declared intent to place a greater focus on supporting R&D, the introduction of new technology will itself enable us to apply our technological capability with an eye on the resilience of our activity, perhaps more than in the past. □

Professor John Loughhead CB OBE FREng FTSE is the Chief Scientific Adviser at the Department for Business, Energy and Industrial Strategy (BEIS). In the summer of 2019, he was also appointed Chair of the Mission Innovation Steering Committee. Mission Innovation is the primary intergovernmental forum to progress clean energy innovation and was launched at COP21 in Paris. John's professional career has been predominantly in industrial research and development for the electronics and electrical power industries.

We saw, during the search to supply PPE, that some of the equipment sourced, although described in a particular way, proved not to be suitable for the standards required in a UK environment.

The debate

In the panel discussion that followed the main presentations, a number of issues were raised, including: measuring resilience; standards; critical infrastructure; and medical supplies.

A question was asked about how companies determine their level of resilience. Most will have an idea of the cost of not being resilient. In fact, companies regularly test their business continuity plans against their ability to respond to events and they will have assessed the likelihood of such occurrences. It was recognised that increased resilience does not always entail additional cost – if resources are distributed across different countries, companies can flex these to match differing financial situations in a variety of locations.

The issue whether standards can inhibit innovation was raised. There is some evidence that they have done so on occasions, so it is important for new standards to be developed on an outcome rather than a prescriptive basis, where scope for innovation is built into the development of such standards. In terms of standards and environmental performance as we move to a low carbon economy, standards could play a role in raising environmental performance although the difficulties of reliable environmental accounting were noted.

Critical resilience

The resilience of critical national infrastructure, particularly communications technology, is critical but the UK needs (working with key partners where necessary) to have sovereign oversight of these. The supply chain for such critical infrastructure has not been well protected in the past, but the UK could identify domestic leaders in different technologies and develop a protected supply chain for hardware, whilst ensuring these companies also invest in skills and R&D, which will help for the development of software. Such infrastructure usually involves complex systems, where the development and management of the system itself is a significant element of the value and IP. It is usual within such systems to have multiple lines of supply for any key components.

The issue of whether supply chains for critical medical supplies should be specifically designated and protected was discussed. Upstream supply chains are heavily interdependent and complex, with many chemicals sharing the same starting materials. That said, in the Covid crisis, the challenge has been more about the transport of materials than merely access to them. There are also different considerations for companies and countries about different medicines – whether they make a 'cost play' for more established medicines or an 'innovation play' for newer medicines.

The nature and resilience of supply chains will be of increasing importance as companies and countries emerge from the Covid pandemic. We remain a world with an interdependency of resource, so hopefully the economic system will be able to generate the recovery that is needed, with strong supply chains. ❐

FURTHER INFORMATION

OECD. Food Supply Chains and Covid-19: Impacts and Policy Lessons
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UK Government. Strengthening UK supply chains: good practice from industry and government
www.gov.uk/government/publications/uk-supply-chains-good-practice-from-industry-and-government

World Economic Forum. Dashboard for a New Economy – Towards a New Compass for Post Covid Recovery
www3.weforum.org/docs/WEF_Dashboard_for_a_New_Economy_2020.pdf

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