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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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The Foundation for Science and Technology
10 Carlton House Terrace
London
SW1Y 5AH

Telephone
020 7321 2220

Fax
020 7321 2221

Email
fstjournal@foundation.org.uk

Editor
Sir John Enderby CBE FRS

Production Editor
Simon Napper

Sub-editors
Wendy Barnaby, Judy McBride, Charles Wenz

Design and layout
James McQuat

www.foundation.org.uk

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www.foundation.org.uk carries reports on all Foundation meetings.

Visa restrictions to hit universities

A group of 16 university vice-chancellors, including those of Bristol, Glasgow, Sussex and Birmingham, have publicly expressed their "profound concern at the damage that would be caused to the UK economy and to [their] universities if the Government's proposals to reduce the number of international students coming to the UK are implemented".

In a letter published in *The Observer* at the beginning of March, the President of Universities UK, Exeter University's Professor Steve Smith, and his colleagues argue that: "International students coming to universities contribute more than £5 billion each year to the UK economy through tuition fees and off-campus expenditure. Reductions in student numbers will lead to reductions in income and jobs.

"Without international students, many university courses, particularly science and engineering ones, may no longer be viable. This will in turn reduce the courses available to UK students. International students bring extensive cultural and political benefits to the UK. When they return to their countries at the end of their studies, they become cultural and economic ambassadors for the UK. At a time of financial austerity, this issue is of immeasurable importance to the UK."

www.guardian.co.uk/theobserver/2011/mar/05/letters-international-student-cuts

'Crucial year' for infrastructure

Crucial decisions need to be made this year in order to deliver low carbon energy for the UK according to National Grid chief executive, Steve Holliday.

Speaking to The Royal Academy of Engineering at the beginning of March, Holliday warned that the UK faces a pivotal year as decisions loom on replacing ageing critical assets with new infrastructure to enable the UK to cut carbon dioxide levels by a third ahead of the 2020 deadline.

He said: "We cannot underestimate the scale of the engineering challenge that will be needed to deliver a sustainable energy future - one which I believe is going to lead to a renaissance in engineering."

He believes the targets are "ambitious and demanding" as a quarter of the UK's energy plants will be retired by 2020. He stressed that the UK must become less reliant on coal and embrace wind power, nuclear options plus carbon capture and storage technologies.

"The biggest increase will be in wind power with current plans set to target 15 per cent of the energy mix by 2030."

www.raeng.org.uk

First Technology and Innovation Centre announced

The Government announced the creation of the country's first Technology and Innovation Centre (TIC) in mid-March. The High Value Manufacturing TIC will be formed from a group of research and technology facilities from across the country.

The new TIC will provide an integrated capability and embrace all forms of manufacture using metals and composites, in addition to process manufacturing technologies and bio-processing. It will draw on excellent university research to accelerate the commercialisation of new and emerging manufacturing technologies. The seven centres are: Advanced Manufacturing Research Centre (Rotherham); Nuclear Advanced Manufacturing Research Centre (Rotherham); Manufacturing Technology Centre (Coventry); Advanced Forming Research Centre (University of Strathclyde); National Composite Centre (University of Bristol); Centre for Process Innovation (Wilton & Sedgefield); and WMG (University of Warwick).

This is the first of a network of Technology and Innovation Centres that will be established by the Technology Strategy Board with over £200 million of Government investment overall. Other centres will be established in technology areas of high growth potential.

Announcing the new venture, Business Secretary Vince Cable said: "Manufacturing is vital to the country's economic stability and our potential to achieve growth. It generates £140 billion a year, accounting for 55 per cent of total UK exports – but it has considerably greater potential. The investment in the new centre will further bridge the gap between universities and businesses, helping to commercialise the outputs of Britain's world-class research base."

www.innovateuk.org/deliveringinnovation/technology-and-innovation-centres.ashx

Grasping the opportunities from IT

Despite spending around £16 billion per annum, Whitehall and Westminster often see IT as a necessary evil: a risk to be mitigated rather than an opportunity to be exploited, according to a report from the Institute of Governance.

System Error: fixing the flaws in government IT was prepared by a high-level taskforce commissioned by the Institute for Government. The report sets out the case for a new approach to IT in the public sector. It concludes that this needs to emphasise adaptability and flexibility while retaining the benefits of scale and collaboration across government. The report concludes that it is necessary to tackle two important aspects simultaneously – delivering government-wide efficiencies of scale and interoperability while facilitating rapid response and innovation at the front line. The taskforce describes these twin tracks as 'platform' and 'agile'. This report demonstrates that by implementing both of these elements, government could see cost and time savings while delivering a more effective and flexible service.

Sir Ian Magee, Chair of the taskforce and Senior Research Fellow at the Institute for Government, noted: "The possibilities IT offers for wholly transforming people's lives increase exponentially with each passing year.

"The good news is that we are convinced there is a much better way forward for Government IT."

www.instituteforgovernment.org.uk/publications/23/system-error

New 'scientific powers' emerging

China, Brazil and India are emerging as major scientific powers to rival the traditional 'scientific superpowers' of the USA, Western Europe and Japan, according to a new report from The Royal Society. The report also identified some rapidly emerging scientific nations not traditionally associated with a strong science base, including Iran, Tunisia and Turkey.

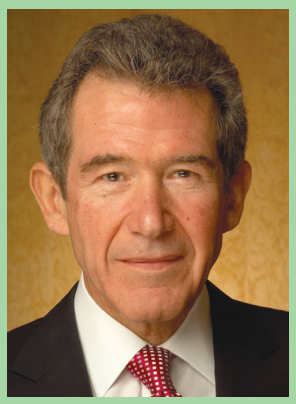
The report, *Knowledge, Networks and Nations: Global scientific collaboration in the 21st century*, analysed a wide variety of data, including trends in the number of scientific publications produced by all countries. It found that China's share in the total number of articles published globally is now second only to the United States.

The publication data analysed by the report showed changes in the share of the world's authorship of research papers between the periods 1993-2003 and 2004-2008. Although the USA still leads, its share of global authorship has fallen from 26 per cent to 21 per cent. China has risen from sixth to second place, its share of authorship rising from 4.4 per cent to 10.2 per cent. The UK remains in third place, although its share has fallen slightly from 7.1 per cent to 6.5 per cent.

http://royalsociety.org/policy/reports/knowledge-networks-nations

Innovation in a time of austerity

John Browne



The Lord Browne of Madingley is President of the Royal Academy of Engineering and a Fellow of the Royal Society. He joined the Board of The British Petroleum Company plc in September 1991 as a Managing Director. He was appointed Group Chief Executive on June 10, 1995. Following the merger of BP and Amoco, he became Group Chief Executive of the combined group on December 31, 1998 until 1 May 2007. He was appointed a Trustee of the Tate Gallery on 1 August 2007 and Chair of the Trustees on 26 January 2009. He was knighted in 1998 and made a life peer in 2001.

These are challenging times for the UK. Following a deep and painful recession, we are now going through a period of unprecedented fiscal discipline. Alongside addressing the deficit, the Government's priority must be economic growth. The UK's investment in world-class research has a crucial role to play in providing the knowledge base for the high-value, high-tech businesses and industries of the future.

Blue-skies scientific research is important, not least because we do not know where the next 'great idea' will come from. However, within a balanced research portfolio, the UK can benefit from increasing the proportion of research that is likely to deliver short- to medium-term economic benefit. We must prioritise research that results in: a technology lead for the UK; the creation of a new industry; substantial enhancements in an existing industry; reduced costs of health and care provision; or a reduction in the UK's carbon emissions.

There must also be more emphasis on the mechanisms for commercial exploitation of scientific and engineering research. The UK needs to get better at turning input into impact, translating the fruits of our investment in research into useful, wealth-creating products and services. The UK cannot afford the current size of its research spending if it does not generate successful high-tech companies from it.

Achieving this will be a challenge. However, we start from a position of strength. Britain is already a leading global innovator and manufacturer. We are strong in many industries but particularly in micro-processing, aerospace, life sciences and creative design. We have world-class research facilities, including three universities in the world's Top Ten.

The Technology Strategy Board is driving progress and new Technology Innovation Centres promise to accelerate the pace of technology transfer from universities to industry.

Creating a workforce with the skills that employers need is another urgent priority. At the Royal Academy of Engineering, we are working with industry and Government to encourage more young people into a career as skilled engineering technicians. For the undergraduate engineer we are promoting a new experience of learning, richly informed by the practical activity of solving real multidisciplinary problems with the assistance of experienced engineers.

Another key issue is culture. We must do much more to inspire and attract young people to engineering from a wide range of backgrounds. We need to identify and support great ambassadors for our profession, encouraging them to get out and communicate – through the media, in schools and in colleges.

The decisions to be made on UK research are part of a wider policy and regulatory environment that must promote our capacity to compete. The Royal Academy of Engineering will continue to play its part, alongside Government and our partners in engineering business and industry, to support the excellent research, the engineering skills base and the policy framework that will drive innovation, growth and – ultimately – an economy that is robust, sustainable and balanced. □

The London Engineering Project promotes the subject to students in the capital's schools.

A key tool in Government decision-making is statistical evidence. On World Statistics Day, 20 October 2010, the Foundation for Science and Technology debated how effectively that tool is being employed.

Crime statistics: how these can guide policy

Bernard Silverman

It is hardly surprising that crime statistics have been the focus of so much attention. Every citizen and organisation is affected (or potentially affected) by crime. Gaining a good overall picture of short- and long-term levels and trends in crime of all types requires subtle methodology that makes use of both administrative and survey approaches. Two areas that show the vital importance of good statistics are crimes against young people and cyber-crime.

Professor Bernard Silverman FRS is Chief Scientific Adviser to the Home Office. In this role he provides independent scientific advice and leads Home Office Science, which includes Home Office Statistics. He holds the title of Professor of Statistics at the University of Oxford, and has served as President of the Royal Statistical Society and as Council Member of the Royal Society.

Crimes against young people

The British Crime Survey (BCS) is one of the main inputs in the production of crime statistics, but at present it covers only crimes among adults. However, there are a number of areas of crime where young people are disproportionately affected and one needs to count younger victims to get a fuller picture. For example, the modal age group for mobile phone theft in 2007-08 was 14-17, and the number of thefts from people aged 10-13 was equal to that from people aged over 55. The BCS is therefore considering how to extend its coverage to crime victims aged under 16. The first experimental statistics on crime against this group were released, together with a call for further consultation, on 17 June 2010.

One of the most interesting issues raised by this experimental release of data was the simple question: what is a crime? Suppose that an 11-year-old punches his 13-year-old brother on the nose in a scuffle in the back garden, and the 13-year-old kicks him back on the knee, breaking the skin. The 11-year-old limps back into the house and complains to his mother, who says, "Did you hit him first? In that case shut up and don't do it again."

From a legal point of view two quite serious crimes have been committed. How, as statisticians, do we address this issue? It is not simply a question of deciding how to count crime; the ontological issue of what we consider to be criminal or even antisocial underpins our attitude to many social and political questions, and once we start to count something, we are prompted to think about it more deeply.

The BCS experimental approach tackles this matter head on by considering four possible definitions, illustrated by the examples in Table 1:

- 'All in law' counts all incidents that are crimes in a strict legal sense, such as the two crimes committed by those brothers in their garden.
- 'All in law outside school' excludes incidents occurring in school. This is a rough approximation to the approach that low-level incidents are usually dealt with by school authorities and are not recorded as crimes by the police.
- 'Norms-based' applies an explicit set of normative rules that excludes relatively minor incidents. These rules were developed from the findings of qualitative research with children that informed the development of the survey.
- 'Victim-perceived' asks the victim if they think an incident was a crime.

The difference in results yielded by these different definitions is remarkable (see Figure 1). 'All in law' leads to an estimate of over two million crimes a year, but only about one-fifth of these are perceived by their victims as crimes. This shows clearly how crime statistics for under-16s force us to consider much more fundamental issues than just the question of how much crime against young people goes unreported.

Cybercrime

Cybercrime is another area where statistics raise new questions. For example, if your credit card details are stolen, sold online and used fraudulently, the bank will usually meet the losses and issue you with a new card, so you may not consciously feel that you yourself have been a victim of

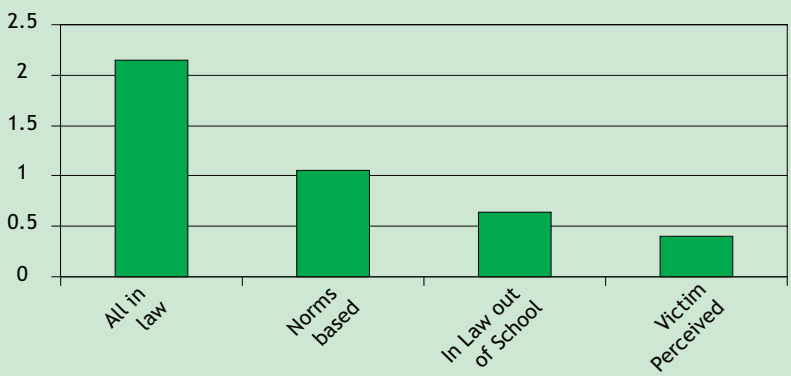


Figure 1. Annual figures (millions) for crimes against young people in BCS Experimental Statistics on Victimisation of Children Aged 10 to 15, 2010.

Examples of types of incident reported by children (for illustrative purposes only; these particular incidents were not necessarily actually reported).	All in law	Norms-based	All in law outside school	Victim perceived
At school, a child has their dinner money of 50 pence taken from them by someone who intended to steal the money. The money is returned some time later. The child considers the incident just something that happens and not a crime.	✓	X	X	X
At school, a child has a favourite inexpensive toy taken from them on purpose and it is not returned. The child considers the incident a crime.	✓	X	X	✓
In the street, a child is deliberately pushed and shoved but sustains no injuries. The child considers the incident just something that happens and not a crime.	✓	X	✓	X
At home, two siblings are playing and one of them deliberately smashes the other's toy. The child who has their toy smashed considers the incident wrong, but not a crime.	✓	X	✓	X
At school, two children get into an argument and one hits the other, giving them a nose bleed. The injured child considers the incident just something that happens.	✓	✓	X	X
At school, a child's trainers are stolen from a school changing room. The child considers the incident a crime.	✓	✓	X	✓
In the park, a child is punched and kicked by another child and sustains scratches and bruising. The child considers the incident wrong, but not a crime.	✓	✓	✓	X
At a children's party, a child has a hand-held video game stolen after leaving it unattended. The child considers the incident a crime.	✓	✓	✓	✓
In the high street, a child has their mobile phone stolen from their pocket. The child considers the incident a crime.	✓	✓	✓	✓

Table 1. Crime and young people: what counts as crime?

a crime. In 2009-10 the police recorded 27,139 cheque and card frauds, but data from both the UK Cards Association and the BCS show that there are millions of fraudulent transactions each year. We have not quite yet worked out how to count cyber-crime; indeed, we have not really worked out what to count.

How can statistics help? If we decide to count something we have to think about what it really is. So a very good first step – which is not as easy as it sounds – is to construct a taxonomy of cybercrime. The statistics will give us an impetus to do that and a proper taxonomy will give us an impetus to work out the right ways of tackling it. Once we have a good taxonomy, we can develop robust ways of measuring it as well.

Given the current debate about the reasons for changes in levels of crime, assessing not only the level of cybercrime but also the efficacy of interventions in the cyber-domain is very important. As in the area of child victimisation, this is a domain where intelligent use of statistical thinking and strategy has a really important part to play in helping policy makers to understand and clarify the real picture.

These two different areas, crime against young people and cybercrime, give a taste of the richness of the contribution that statistics can make. They indicate the deeper issues that have to be considered if crime statistics are to produce measures that are both reasonable and trustworthy. □

Asserting the impartiality of official statistics

Michael Scholar

There was a strong feeling a few years ago that 'something needed to be done' about official statistics. People had become mistrustful of them and wanted them put on an independent footing, as had happened with the Bank of England in relation to monetary policy. Surveys showed that only one-in-six people believed official statistics were not being manipulated by ministers, while three out of five thought there was some dishonesty about the way in which official statistics were collected or published. The Statistics Authority was created in April 2008 to change that situation and to give people reason, through the Authority's actions and words, to trust official statistics.

Public mistrust

What leads people to mistrust official statistics? The answer is complex. People remember episodes in the past which suggested that official numbers had been manipulated for political purposes – for example, the 18 re-definitions of unemployment in the 1980s and 1990s, each diminishing the total. A second rea-

son is the very healthy scepticism that some people feel about any Government pronouncement. A third is the human propensity, especially notable within the media, to take those in authority down a peg or two, which sometimes causes people to lose sight of the notions of impartiality and objectivity. There may be a type of innumeracy in the population that results in some people being totally bewildered by – and mistrustful of – numbers. Finally, people may have unrealistic expectations of what statistics can tell us.

On this last point, I strongly support the initiative taken by David Hand and the Royal Statistical Society to establish a 10-year statistical literacy campaign, called 'GetStats', which was launched on World Statistics Day, 20 October 2010. This campaign is designed to build statistical understanding across society and to ensure that we get the most out of our data. I believe that campaigns such as this will play a vitally important part in tackling innumeracy and bewilderment, thereby helping us to give people more reason to have trust and confidence in official statistics, through understanding and knowledge.

The Statistics Authority attempts to assist the wide range of users in guiding their actions and their understanding of both British society and economy. It aims to maintain high professional standards in the production of statistics, and it tries to ensure that statistics are well explained (including their strengths and weaknesses) so that they are meaningful and helpful to those who need them. We can shorten this to a threefold mantra – right statistics, right methods, right explanation. The more we can achieve these objectives and aims, the more the trustworthiness of UK official statistics will increase and, so also, the degree of trust that people actually place in these statistics. In my view, the task is unambiguously worthwhile, one which needs to be undertaken and one in which we absolutely must succeed.

Improvements in all three parts of the mantra is a long, hard job, which can only be achieved by statisticians themselves. It is particularly difficult when statistical budgets will be, very probably, sharply reduced. Statistics must, of course, take its share of public expenditure reductions, but we must never forget that good statistics are vital if we are ever to know the effects of new Government policies on society and the economy.

I wrote to the leaders of the major parties before the election. I asked them to strengthen the authority of the National Statistician over the statisticians working across Government departments. I asked them to involve the Statistics Authority in decisions to reduce Government expenditure on statistics and to tighten up the rules for pre-release access – these are the rules that allow ministers and their political advisers to see official statistics 24 hours before they are published.

Sir Michael Scholar KCB is Chair of the UK Statistics Authority. He is President of St John's College Oxford as well as a Pro-Vice-Chancellor of the University. He was previously Permanent Secretary of the Department of Trade and Industry and Permanent Secretary to the Welsh Office. Sir Michael has held posts as a Research Fellow at St John's College, Cambridge, and an Assistant Lecturer in Philosophy at Leicester University.

I had a friendly reply at the time from David Cameron. Yet I have since been told officially by the Cabinet Office minister that, although the Government supports our work, it does not agree to any of these proposals. That is a disappointment. However, we have decided to collect as much information as we can about the forthcoming cuts in statistical capability and output, and to report any concerns we have to ministers and to Parliament. It might, for example, transpire that a modest and apparently inoffensive reduction in one department's statistical output would do disproportionate damage to another's or to the statistical system as a whole.

Demonstrating independence

The Statistics Authority clearly needs to demonstrate the independence of official statistics from political interference. It is easy to exaggerate the scale of the problem here. Government statisticians are professionals whose impartiality and objectivity, in my 40 years experience of Whitehall, is respected by policy makers and administrative colleagues. Yet there is always a temptation (or people think there is a temptation) for ministers or their political advisers to suggest changes – to the date of a statistical release, its presentation or format, or some of the definitions. There is also the risk of selective quotations from unpublished data or a one-sided account of a complex statistical picture.

So, the Statistics Authority has intervened publicly when it has seen evidence of political interference with, or manipulation of, official statistics. Examples include statistics on knife crime, migration, the gender pay gap and violent crime. We recognise that interventions may have had a perverse effect in the short term by diminishing trust in official statistics. Yet the longer-term effect will, I am sure, be beneficial, not least by materially strengthening the positions of professional statisticians within Government departments.

To take one example, we intervened when we became aware that local crime statistics were being disseminated in such a way that they were likely to mislead the public. Appropriate account was not taken of changes in recording practices during the period of comparison, and there was no explanation of the effect these changes may have had. The extent to which these statistics had been disseminated – to all types of national, regional and local media – was of great concern to us.

Appropriate measurement

This intervention re-ignited debate about the best, or most appropriate, long-term statistical measurement of violent crime. It also encouraged a proliferation of analyses using the available data, some more statistically robust than others. However, by re-launching this debate we encouraged those who wish to use and disseminate these statistics to do so responsibly, explaining what the statistics show and what they do not.

We proposed the establishment of a non-executive board to supervise the production of crime statistics and provide much-needed independent reassurance. We also proposed that statistical publications on crime and criminal justice should be brought together so the non-expert user can understand the flow of offences and offenders through the system. Finally, we recommended the production of a regular commentary by the National Statistician on the statistics themselves, with information on the different sources of the data and discussion about the relative strengths and weaknesses of the statistics. These proposals are the beginning of a dialogue. I hope that everyone with an interest will join us in this dialogue and that the end result will be a growth of trust not only in crime statistics, but in other types of official statistics as well. ☐

A better understanding of statistics

David Hand

I sometimes describe statistics as providing a window on the world. By this I mean that statistics reveal structures, properties, characteristics and relationships that are otherwise concealed. However, just as looking through a window does not tell us everything about the world outside, so statistics cannot tell us everything. We have to decide where to focus our attention, and from which angles we should peer.

This question of perspective is critical. Different perspectives reveal different things about the world and can sometimes seem contradictory. For example, I recall hovering between amused and appalled by a university ranking scheme which included as an input variable the number of papers published in *Nature* and *Science*: this consequently gave a very low rank to the London School of Economics! Bernard Silverman's outline of crime statistics illustrates perfectly the potential for confusion when different definitions of crime are used.

The key message is that different measurements capture different things. And it follows that, unless one has a highly specific aim in mind, it is probably dangerous to rely on a single summary statistic. I am sure you are all familiar with the parable of the elephant and the blind men: each of them had an entirely different notion of what an elephant was, based on their individual limited perspectives.

It is certainly true that focusing exclusively on a single perspective leads us down the slope of Goodhart's Law, which states that any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes. It also means that non-targeted aspects of performance may deteriorate to unacceptable levels. Recall the classic example of the nail factory that met its target of weight of nails by producing a single gigantic nail.

The Statistics Authority's 2010 report *Overcoming Barriers to Trust in Crime Statistics: England and Wales* says: "Having two different sources can undoubtedly cause confusion ... but the answer is not to change either of them fundamentally. The two sets of statistics throw different lights on the incidence and experience of crime and we need both of them..." It goes on to say: "It is the job of the professional statistician in Government to filter the signal from the noise and explain the results in a way that is trusted." But is that quite right? Bernard Madoff explained his investment results in a way that was trusted. It did not mean that they *should* have been trusted, or that they should not have been subjected to rigorous examination.

Professor David Hand FBA is President of the Royal Statistical Society and Chief Scientific Adviser at Winton Capital Management. His research interests include multivariate statistics, classification methods, pattern detection, the interface between statistics and computing and the foundations of statistics.

Critical assessment

What we really need to promote is a critical assessment of statistics in general. Sir Michael Scholar argued that we need to give people more reason to have trust and confidence in official statistics, through understanding and knowledge. That is the key: we need to enable people to recognise the 'building blocks' but also to have elementary building expertise, so that they can see for themselves that the statistical structures are sound.

Critical assessment includes an evaluation of the source of the statistics. One hopes that the public recognises and appreciates the painstaking rigour that goes into the collection of Government statistics by official statisticians. And one might hope the public would be able to contrast this with the bizarre lack of rigour that goes into such things as man-of-the-year polls. One might also hope that the public would appreciate the absurdity of university league tables based on student surveys in which the respondents are self-selected.

So the emphasis needs to shift from trust towards critical assessment, the latter being in reality a precursor to the former.

One can mistrust statistics because one doubts their accuracy. One can also mistrust the intended use to which statistical descriptions will be put. This 'conspiracy theory' of Government statistics needs to be tackled by helping people understand the uses to which statistics are put, and the benefits that will derive from them.

Misconceptions

Why are there such widespread misconceptions about statistics? Aside from lack of trust, two possible reasons are innumeracy and 'number phobia'. A third is a failure to appreciate that statistics are supposed to change as time elapses or as more data become available. If a statistic is updated, this is not the mark of a poor initial analysis but of an increasingly refined measurement procedure or more data.

A fourth factor may be a failure to recognise how wide the impact of statistics is. Without statistics we could neither create nor monitor housing policies: we would not know where the greatest needs were, where to locate a new retail outlet, how our local schools or hospitals were doing, or how to adapt our transport policies. And we would not know whether crime was increasing or decreasing.

The role of the media in helping the public understand statistics is critical. The onus is on the media to recognise that rather than bending the truth to permit a pseudo-answer that is readily comprehensible without effort, it is necessary to make the effort to understand the unbent truth.

And the public includes politicians. I have raised issues such as the importance of the census with representatives of both the previous and the present administration. Census data will be used to guide the distribution of a trillion pounds of public money to local authorities over the next 10 years, at a cost of less than one-half of one-tenth of one per cent of that amount. That sort of efficiency ratio is one most commercial organisations would be proud to achieve.

It is vital that the view from the window of statistics is not obscured by uncoordinated cuts in statistical measurement across different departments. There can be few issues that span Government departments in the way that statistics does, so a piecemeal approach to cuts courts disaster.

It is perhaps even more important for politicians to understand the view from the window of statistics than for the wider public. Yet anyone who is not educated in statistical understanding is staring at a window with the blinds shut. Our 'GetStats' campaign aims to promote that understanding. Let us hope we can achieve that understanding before we progress too far into the 21st century! □

GetStats Campaign – www.getstats.org.uk

Should government science advisers be more involved in risk assessment? Are there parallels in the business world from which lessons can be learned? The questions were discussed at a meeting of the Foundation for Science and Technology on 10 November 2010.

Understanding and responding to risk

John Beddington

What happens to change a risk into reality and how does the Government respond? I will focus on three areas: on civil contingencies; on climate change; and on the risks in financial markets (which is the subject of a forthcoming study by the Government's Foresight team).

The 2010 edition of the UK *National Risk Register* still shows pandemic disease as having the highest combination of probability and impact (Figure 1). Other major threats include terrorist attacks on crowded places and on transport, severe weather, coastal flooding and animal disease.

How is this register compiled? First, to assess the likelihood of this occurring, historical evidence, predictability (with weather events for example) and expert advice are taken into account. The plausibility of such an incident also needs to be considered under the headings of intelligence, capability, intent and vulnerability.

Second, there are the likely impacts: the number of deaths and casualties, the extent of social and economic disruption as well as, interestingly, psychological aspects (i.e. the way in which the public reacts to these problems).

The concept of a 'reasonable worst case' may need refining. The reasonable worst case for the swine flu epidemic in 2009 was built from a combination of what happened in the epidemic in 1918 and what H5N1 might produce. This delivered a figure in the order of 650-750,000 deaths – the press took this as a prediction while in reality the total figure was a couple of orders of magnitude lower.

Volcanoes

The 2010 National Risk Register did not include volcanoes. Yet there are around 30 active volcanic systems in Iceland. There are about 25 eruptions every century, so on average about once every four years. A significant eruption might be expected every 20 years or so. There are also periodicities which indicate that the last 50 years have been relatively quiescent. With so many volcanoes in Iceland, including this in the risk matrix would seem to be reasonable. Next to Eyjafjallajökull, the volcano that exploded in April, is Katla. If this erupted, something in the order of 30 times more material may be ejected into the atmosphere. There are also other events which have a very low probability but would have enormous impact, such as an eruption the scale of the 1883 eruption of Krakatoa.

Now there are many volcanoes. The risk only becomes actual when the volcano erupts and (in the case of Iceland) there is a north to north-westerly wind causing significant disruption to air space. I am focussing specifically on risk here, so I will not go into the way regulation then comes into play – although that is clearly important.

In the last couple of years, people in the academic and industrial communities have been invited to regular reviews to discuss general scientific or engineering questions. The most recent of these 'Blackett Reviews' looked at low-probability/high impact events like Krakatoa.

So that is how risk is assessed. The next question is what should be done when the risk becomes reality? Taking the Icelandic volcano again – the major impact was nothing to do with human or animal health, but with disruption at travel plans being significantly interrupted. The UK Civil Contingencies Committee was convened in the Cabinet Office Briefing Room (COBR). This was in the middle of the election campaign which complicated matters a little, but that could happen in any emergency. Sometimes the Committee was chaired by the Prime Minister, sometimes by the appropriate Secretary of State for the lead department.

Sub-groups set up under the Scientific Advisory Group on Emergencies (SAGE) tackled the aviation and engineering issues – and there were also meteorology, geology and volcanology sub-groups. Input from the Met Office (part of the MOD), the British Geographical Survey (part of Natural Environment Research Council) and experts in the Research Councils and academia was key. Engaging a wide community of experts has enabled this group to explore the risks from further volcanic eruptions. The event lasted a relatively short time: however, the SAGE convened at the time of the swine flu outbreak lasted for a significant period of about six or seven months.

Climate change

Climate change is a widely discussed topic but that does not make it any less relevant. There is enormous variation in the UK's mean temperature. Yet as we go through the period up to 2007, the occurrence of cold weather becomes significantly less frequent while hot weather becomes more so.

The Hadley Centre has put together a report – at the request of the Foreign Office – about the global impact of a 4°C rise in temperature. The assessment was made by looking at something like 27 different models and realisations of models, from the most optimistic to the most pessimistic. The most optimistic would give a rise in the Arctic of, at best, 8°C; and worst 16°C. How can this be taken into account in planning strategy?

If we put the risks of climate change onto a normal risk matrix (I am not aware this has yet been done), in terms of the likelihood that sea levels will rise or the risk to forests, I wonder if that would convey more information than the worst case projections we often use? It might facilitate discussions of the relative likelihood of these events and their relative impact in particular regions.

Sir John Beddington CMG FRS is Government Chief Scientific Adviser, Government Office of Science. His main research interests are the application of biological and economic analysis to problems of natural resource management including: fisheries, pest control, wildlife management and the control of disease. He has been at Imperial College since 1984, where he has headed the main departments dealing with environmental science and technology.

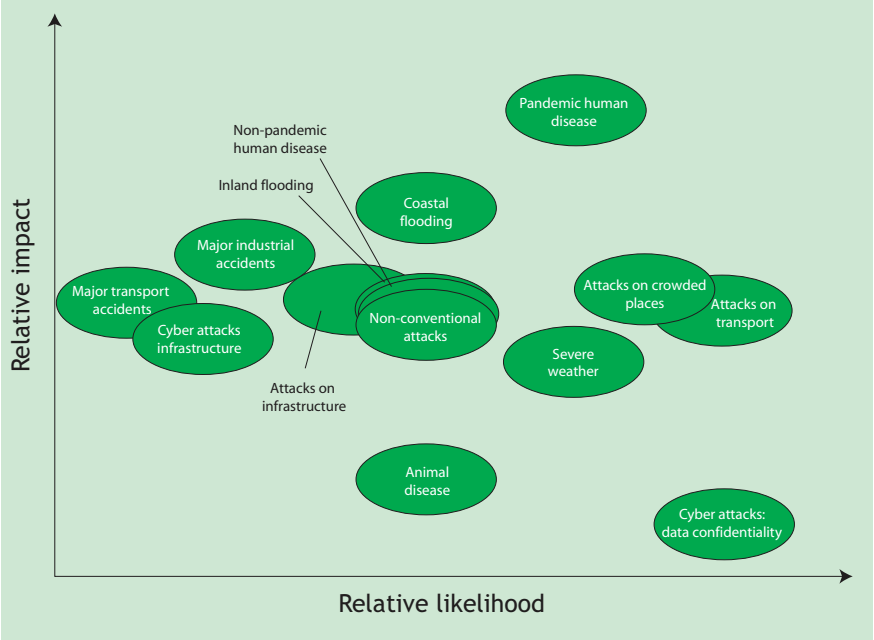


Figure 1. Risk matrix. Source: National Risk Register 2010 Edition (definitions appear in the report).

High-frequency financial trading

The Foresight study is investigating how computer trading (including both algorithmic and high-frequency trading) is likely to evolve in the next 10 years. The volume of equities traded through computer-automated trading – taking place at high speed and with little human involvement – has increased dramatically in the past few years. Today, over one third of the UK equity trading volume is generated through high-frequency, automated computer trading while in the USA this figure is over a half.

This has resulted in stock exchanges competing to attract traders by offering ever lower latencies. The London Stock Exchange-owned Turquoise platform recently claimed to offer the fastest trading speeds in the world; other exchanges are quick on their heels.

What does this mean for the broader financial system, or, indeed, does this matter to anyone outside 'finance'? Any computerised system (or even just a portion) operating at ever higher speeds and ever larger volumes is likely – just in terms of maintaining stable networks – to face challenges. The 6 May 2010 'Flash Crash' saw major US equity indices fall 5-6 per cent in a matter of minutes, before rebounding almost as quickly. For a very short period of time, some stocks were valued at effectively 1 cent while other stocks were valued at over $100,000. This short event led to almost $70 billion being withdrawn from US equity funds in the immediate aftermath, and continues to influence investor confidence today.

Investigations into the event have proposed various explanations. While 'high-frequency trading' has been absolved of responsibility for causing the crash, the interaction of algorithms in uncertain or unpredictable market conditions raises serious questions for financial markets and all who depend on them.

The Foresight project is examining the future of computer trading in financial markets and their financial stability. Economists, physicians, sociologists, computer scientists, mathematicians, investors, traders and other experts will ask, and be asked, important questions about how this is likely to evolve.

In our world, there will always be problems, so there will always be risks and a need to address those risks. As Cicero said: probabilities direct the conduct of a wise man. □

www.cabinetoffice.gov.uk/resource-library/national-risk-register

Why don't/won't they listen?

David Omand

A refrain often heard among those frustrated by resistance from those in authority to accepting scientific, risk-based analysis is 'why don't/won't they listen?' Let me draw on an unusual example, that of secret intelligence, to illustrate some of the complexity of the relationship between the analytical and policy worlds.

Intelligence is itself a risk-based activity. Its purpose is to help optimise decision-making by reducing ignorance on the part of Government, thus improving the odds that security objectives can be achieved.

Intelligence can provide situational awareness – the 'who, what and where' of the threats we face. It can help supply an explanation – answering the questions 'how', 'why' and 'what-for'. With a good explanation consistent with the available facts, it may be possible to predict, 'what next' or 'where next'. Even better, a model can be constructed to explore the 'what if' questions. And intelligence can help provide strategic notice of possible futures – not predictions, but possibilities that can stimulate further research.

Intelligence is often fragmentary and incomplete (and it will sometimes even be wrong) but used sensibly it shifts the odds in our favour. Yet consider everything that has to go right for the policy maker or military commander to act properly on the intelligence.

Sir David Omand GCB is Visiting Professor, War Studies Department, King's College. He was the first UK Security and Intelligence Coordinator, responsible to the Prime Minister for the professional health of the intelligence community, national counter-terrorism strategy and 'homeland security'. Sir David served for seven years on the Joint Intelligence Committee. His book, *Securing the State*, was published in 2010.

Secrets and mysteries

First, there have to be data to collect 'out there' and the intelligence agencies have to find a smart way of accessing that data. The intelligence community has long acknowledged a distinction between the ability to assess 'secrets' and 'mysteries' (and there is an equivalent in

Analysts	Decision makers
• Want to explain the world	• Want to change the world
• Try to stick to the evidence	• Will challenge the relevance of evidence
• Will tend to caution in estimates	• Want options kept open
• Use complex language	• Know that it is necessary to over-ride objections
• Take the time necessary	• Need certainty in public
• Seek impartiality	

Table 1. Psychological profiles of analysts and decision makers. Adapted from: Squaring the circle – dealing with intelligence-policy breakdowns, K L Gardiner, Intelligence and National Security 6/1 (1991).

science). With a *secret*, the data points actually exist, the problem is to access them and interpret them. The secret can in principle be revealed, although of course circumscribed with error bars around the answer.

With *mysteries*, the data points do not yet exist because, for example, the dictator has not yet decided whether he will invade the neighbouring country or the demonstrators have not yet marched on the Presidential Palace. There is no direct evidence, only inference from past behaviour and from current capabilities. Yet someone must assess for the decision makers the likelihood of such eventualities.

Who is best placed to carry out the assessment of mysteries? Does the intelligence community preserve its purity and say: "No, that is a policy matter, we only do analysis based on the secrets we have"? If left to the policy community, the risk arises that the assessment will unconsciously reflect the hopes of the decision takers. At least the intelligence community should be able to apply a robust methodology and some degree of peer review in coming to a judgment. If the intelligence (and scientific) communities do venture judgments about 'mysteries', it is essential that such assessments can be distinguished from those for which there is direct evidence.

Second, analysts have the difficult task of interpreting the fragments of intelligence. There is a great deal in the academic literature about analytic pitfalls. For example, there is 'perseveration', i.e. sticking to an hypothesis long after fresh evidence should have caused re-evaluation, and 'mirror-imaging' when we assume the opponent will think the same way as ourselves. Science, of course, knows too about the 'observer expectancy' effect with its resulting scandals. A reputation for professional independence must be safeguarded – it is easier to lose than build up again.

Third, the assessments must be conveyed in an understandable form and in sufficient time. There is little point in delivering the assessment the week after the crucial decision has been taken. And it has to be relevant, which means that the analysts have to be very close to the policy makers and the nature of the decision, but without allowing themselves to be influenced by the desires of the policy makers.

Finally, policy makers have to understand – and be willing to accept – the significance of the assessment and also be in a position to act upon it. Consider the kind of risks decision makers have to take into account. Faced with threats to our security, there are the risks of lives lost and property damaged, disruption to critical infrastructure, output lost, damage to domestic confidence, the effect on the markets (an important consideration) together with all the media and electoral impact due to the fact that we live in a parliamentary democracy.

Decision makers and analysts

Decision makers have a complex set of trade-offs to make in a psycho-dynamic environment distant from that of the analyst. They are liable to look at the evidence in a different way because they are often different kinds of people (Table 1). Typically, the decision makers are in that position because they chose a career suited to their personality – as doers not thinkers. They want to influence events, they want options but not just those suggested by the analysis. If someone has come to believe they can change the world around them for the better, then their attitude to intelligence (or to scientific evidence) may not appear as objective as the professional analyst might expect.

Decision makers need to be reminded that low risk does not mean no risk: improbable correlations of events do sometimes occur, as the financial sector has recently shown. Attempts to eliminate all risk can produce unwanted consequences creating more harm than good, as some counter-terrorism policies have shown. It will never be easy to explain risk management to the public. Few ministers will relish having to explain publicly that there is a significant risk that their chosen policy will not deliver the results and yet still defend it as the best option on the balance of probabilities. Yet levelling with the public about risk is necessary for good government in a democracy.

Intelligence has its unique features, but I hope this highly simplified account will nevertheless resonate with those who have to champion scientific rationality more widely. □

Using scientific analysis to improve risk management

Dougal Goodman

In 2006 I exchanged correspondence with the Chief Secretary of the Treasury about systems in place, particularly in HM Treasury, to evaluate the impact of low probability, high severity events on the economy. He responded by saying systems were in place to assess such risks but I am still not convinced that the full portfolio of analysis tools available were used during the management of the sharp downturn of 2008-2009. There is still no Chief

Professor Dougal Goodman FREng is a Visiting Professor at The Risk Centre at Cranfield University and at the Institute for Risk and Disaster Reduction at UCL. He is also Chief Executive of the Foundation for Science and Technology and does consulting work for the insurance sector. His interest in risk management began when he was Head of Safety for BP's global operations and as project manager for a study for the Board on whether BP should buy reinsurance. He has had a lifelong interest in the polar regions, serving as Deputy Director of the British Antarctic Survey and leading many expeditions to the Arctic and the Antarctic.

Scientific Adviser at the Treasury.

Each year, the Financial Services Authority publishes an horizon-scanning paper – the *FSA Outlook*. This did hint at the possibility of the financial crisis ahead but the depth of the problems faced by the banking system was under-estimated. Afterwards the crisis was described by the FSA as the result of "a self-reinforcing cycle of exuberance". The regulator has recommended that new risk management systems should be put in place. How well has this been done?

Most quoted companies follow the *Corporate Governance Code* published in July 2010; this recommends that companies should improve their risk management processes. Do companies have the tools to do this and are scientific methods being applied to estimate risk?

Insurers will soon be subject to a tighter regime for regulating how much capital they should hold. Solvency II puts the responsibility on management to build and use better risk management models.

A natural catastrophe – the 2007 UK floods – was a wake up call to many companies about their resilience to natural catastrophes. There was a close call – the losses could have been much worse if the Warham electricity substation had been inundated. The Pitt Review set out many recommendations to improve the response to future flood events.

Science and engineering play an important part in quantifying the impact and estimating the likelihood of such events. Decision makers, scientists and engineers must work together to anticipate such events.

Assessing risk

Senior managers need to stand back from day-to-day operations and regularly review the 'deep downsides' that could destroy their businesses. Companies face multi-faceted deep downsides. Some can be quantified, others cannot: business interruption from natural catastrophes can be but the outrage of the public cannot. Financial failure can occur in many ways including: loss of market for goods or services; loss of trust in management; changes to regulatory frameworks; losses from natural catastrophes such as flooding.

For example, consider ship owners who are exposed to very large liability claims from a range of events e.g. water damage to a cargo of rice, polluting the beaches with oil, killing or injuring the passengers or crew, or damaging harbour facilities. Mutual Protection and Indemnity Clubs (P&I Clubs) provide cover to ship owners for these types of risks. The challenge for the manager of a P&I Club is to manage the cash flows in and out of the Club – he or she is managing an integrated investment and reinsured system which will be impacted by large, rare events from time to time. To manage the exposure, Club managers buy reinsurance, set investment strategies, enforce an inspection regime for the vessels insured and manage litigation. The goal is to maintain reserves at an optimum level. If reserves are too large, the ship owners complain that their funds are unnecessarily tied up; too little and they are concerned about unexpected extra cash calls and regulators about financial failure.

The reinsurance is bought in layers. Currently a loss of $0 million to $8 million is retained in the Club, $8 million to $60 million is shared between all 13 Clubs and above that reinsurance policies are bought in the global market. A substantial proportion of the cover is provided by Lloyd's of London. The Clubs need to answer two questions – how much risk should they retain and if risk is transferred into the market how much should they pay for this transfer? The Lloyd's underwriters need to assess the risk exposures to decide what price they should charge. Science – particularly statistical analysis – can only go so far in answering these questions.

Many business problems of this kind are characterised by time series with underlying trends but occasional, abrupt step jumps. Sometimes the jumps are driven by quite different processes from the more regular events. It is these step jumps that business managers need to be aware of – too often managers are lulled into a false of security because they have not experienced a low probability, high severity event or because these arise from the set of 'unknown unknowns'. For example, the loss of business experienced by aviation through the closure of UK air space due to the ash cloud was a surprise event for many managers in the sector, even though scientists were well aware of the possibility of such an event.

Too often, perceptions of risk are framed by a belief that normal distributions explain most variables. For a normal distribution, excursions larger than two standard deviations from the mean are rare, while in practice some outcomes are characterised by fat-tailed distributions for which this is not true.

Communication

Analysis of the risk is not the end of the story – communicating the outcome of a model and, importantly, the uncertain-

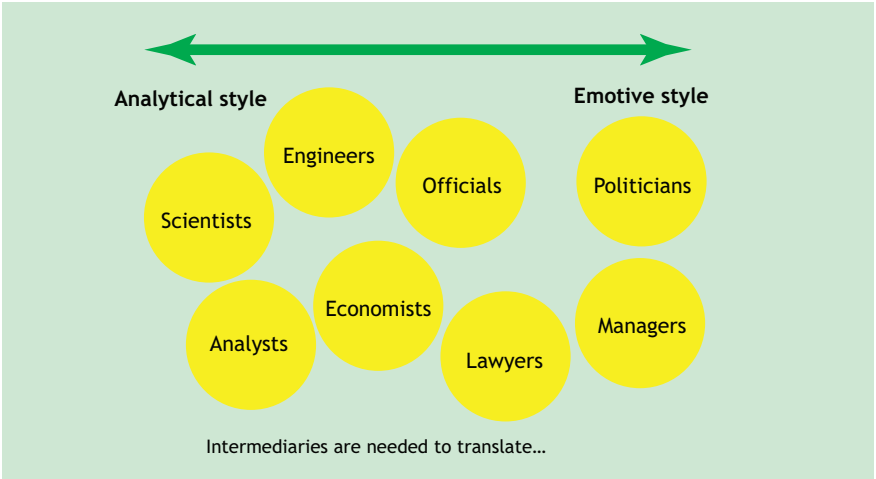


Figure 1. Styles of scientists and decision makers.

ties of the model to senior management or ministers is a major challenge. And there is an important question of who selects which risks to discuss with senior management – the analyst's filter that Sir David Omand talks about in his book, *Securing the State*.

Analysts cannot make a decision on what is acceptable and what is not – such choices should be made by company boards or by ministers. Yet the senior management of a company or ministers are often overloaded with information; the risk adviser is but one small cog in the machinery. The fog of war may hide analysis of important risks.

The manager or minister, however, is making the decisions. Should I buy the company – yes or no? Do I commit resources to this project – yes or no? Should I respond to this threat – yes or no? Is this structure safe – yes or no? These are all binary choices, many of which will be made by 'gut feel', with the analyst's model merely painting a picture of the context.

Scientists and analysts need to recognise that a well argued analytical argument may not carry the day when a politician or senior manager is swayed by other forces. Figure 1 shows the span of decision-making styles that exist in an organisation. An analytical argument will not sway a business leader who makes decisions by gut-feel, or a politician sensitive to outrage from his constituents.

In summary

- Government and industry should share best practice in assessing low probability, high severity events;
- Senior managers should stand back from day-to-day operations and think about the deep downsides that could destroy their businesses;
- Communication of extreme value analysis is not straightforward – a new language for communicating risk in business and government is required. Statistical rigour and analysis is a framework for discussion of risk. □

www.fsa.gov.uk/pubs/plan/financial_risk_outlook_2010.pdf
www.frc.org.uk/publications/pub2526.html
www.environment-agency.gov.uk/research/library/publications/33889.aspx

An overview of the debate

David Spiegelhalter

The three previous contributors challenge us to examine the limitations of analytical and numerical approaches to risk. Professor Goodman highlights the difficulty of communicating analyses to people who, in the end, make the decisions. He believes we need a new language for this communication, but is putting great store on insurance-based approaches to risk. When people have to decide what premiums to set, they are not concerned with the broad range of possibilities ministers and politicians have to consider.

The issue ultimately comes down to whether we can put numbers on these events. The World Economic Forum's *Global Risk Landscape* is explicit about their probabilities and while the Cabinet Office does not publish probabilities in its *Risk Register* they are available, at least in broad orders of magnitude. But Sir John Beddington acknowledges that when items are added to the Register precise figures may be impossible to ascribe, given the real uncertainties about outcomes.

Sir John also uses the phrase 'reasonable worst case', but what does this actually mean? Can a number be put on it? Does it mean 1-in-200 which the insurance industry tends to use? Furthermore, how can a figure communicate the enormous number of assumptions which underlie such quantifications?

Professor David Spiegelhalter OBE FRS is Winton Professor of the Public Understanding of Risk, University of Cambridge. He is also a Senior Scientist in the MRC Biostatistics Unit. His background is in medical statistics, particularly the use of Bayesian methods in clinical trials, health technology assessment and drug safety.

The insurance industry's goal of a numerical probability with which to calculate a premium becomes much more difficult when dealing with deeper uncertainties. That is why I like the type of analysis by Renn that Sir John presented. Renn comes from a social science background, and employs 'blobs' whose relative size provides a means of describing issues where there are not only deep uncertainties but deep disputes about the potential consequences. This is a way of acknowledging the limitations of science in dealing with many really challenging issues.

Sir David Omand argues that analysts have to 'disclose fully the limitations and caveats of the assessment'. This is the nub of the matter but how is it to be achieved? Scientists and analysts trying to take an insurance-based numerical approach know at the same time that they are relying on assumptions. This concerns the acknowledgment of *indeterminacy* and *ignorance*.

Standard methods of analysis deal with recognised, quantifiable uncertainties, but this is only part of the story, although as scientists we tend to focus at this level. A first extra step is to be explicit about *acknowledged inadequacies* – things that are not put into the analysis such as the methane cycle in climate models. These could be called 'indeterminacy'. We do not know how to quantify them but we know they might be influential.

Yet there are even greater unknowns which require an essential humility. This is not just ignorance about what is wrong with the model, it is an acknowledgment that there could be a different conceptual basis for our analysis, another way to approach the problem.

There will be a continuing debate about the process of communicating these deeper uncertainties. There is of course a risk that the analysis might then be disregarded because policy makers want more confidence and certainty. That would be unfortunate: acknowledging uncertainty in science does not mean robust conclusions cannot be drawn. □

The role of coordinated research across the European Union is set to grow. The opportunities to be gained from greater UK involvement in the process were considered at a meeting of the Foundation for Science and Technology on 17 November 2010.

The outlook for science in Europe

Leszek Borysiewicz

Collaboration in European research partnerships is often misunderstood or viewed with apprehension in the UK. Yet it is fundamental to continued success in science here. When the UK engages in Europe, its scientists outperform those of any other nation: our scientists are more than able to compete. More constructively, UK scientists can help Europe to succeed. Furthermore, the opportunity to engage with strong scientists throughout the EU will enhance the UK's reputation throughout the world.

The EU 2020 Strategy, published in early 2010, recognises that Europe faces many problems. It identifies structural weaknesses in the recession that we have just faced. There was low growth throughout Europe and employment was relatively low. Ageing is rapidly catching up with Europe as a major issue, along with climate, energy and global finance. The Strategy also recognised that Europe's strength will be an interdisciplinary approach and there must new ways of encouraging this.

The European Research Area (ERA) is now enshrined in European law. It promotes the rapid movement and tractability of research, scientific knowledge and technology. It guarantees freedom of movement for researchers between EU states. It seeks to underpin the innovative research that is vital for the EU by the end of the decade.

As part of Europe's research agenda there is the Seventh Framework Programme (FP7). The UK is very successful with FP7 applications, just as it is in European Research Council applications. The next framework programme is already under consideration although I know through Research Councils UK (RCUK) that many parts of the UK are not yet actively engaged in the process.

Three objectives

The 2020 Strategy aims to allow Europe to create growth that fulfils three objectives, being firstly smart, secondly sustainable and thirdly inclusive. Seven flagship initiatives support these three aims. Under Smart Growth are: a Digital Agenda for Europe to ensure that we all able to take advantage of the digital era; the Innovation Union, the major platform through which both basic and applied science will be supported, on which I shall expand further; and Youth On the Move which aims to empower younger people to engage with the European vision.

Sir Leszek Borysiewicz FRS FRCP FMedSci is Vice-Chancellor of the University of Cambridge. He was Chief Executive of the Medical Research Council (MRC) from 2007 to 2010, and from 2001 to 2007 was at Imperial College London, where he served as Principal of the Faculty of Medicine and later as Deputy Rector. He was knighted in the 2001 for his contribution to medical education and research into developing vaccines.

Sustainable Growth focuses on a Europe that becomes much more resource-efficient, with an industrial policy for the era of globalisation that is supportive of the environment.

The Inclusion Agenda is needed in order to retrain large numbers of individuals so that they can take advantage of the focus on innovation. It will provide real opportunities, with a target of 40 per cent of young people entering Higher Education across the EU – a challenging agenda indeed.

The Strategy also addresses the social ill of poverty: innovation can help alleviate the worst of the impacts.

Innovation

I return now to the Innovation Union, one of the seven flagship initiatives within the Strategy. One of its aims is to help academia and industry work more closely together. It therefore has a strong research element: science is an 'underpinning platform'. The importance of intellectual property and patents is recognised. The Innovation Union has the aspiration of a single EU patent and a single EU patent court, allowing small and medium sized enterprises (SMEs) greater flexibility, with greater protection for their intellectual property.

The European Commission's main role is to monitor the impact of these agendas rather than set them. Setting them is reserved to the European Council, so the member states are intimately involved in this agenda. Like it or not, this will influence the policies that the Research Councils here will ultimately pursue, just like their counterparts in Europe, because that is how the programme is constructed.

It is not yet clear how the European innovation platforms will work, which means the UK has an opportunity to help shape them. The major challenges are clear: energy, security, transport, climate, health, ageing and environment. The Commission is to monitor overall targets.

There is a continued commitment to dedicate 3 per cent of GDP to R&D. Many thought that target would disappear, but it remains – although our current performance does not compare favourably with the USA at 2.6 per cent or Japan at 3.4 per cent. China too is investing and when it matches the USA's 2.6 per cent of GDP, competition will really begin. So it is vital we in Europe meet our target and quickly.

The UK will engage in the Innovation Union through a number of routes. Apart from direct Government involvement, there is RCUK (particularly the Research Councils' EU group), Universities UK, learned societies and other stakeholder groups. Individual universities will be represented in these groups as important research providers. There are programme committees and expert groups. The Department for Business, Innovation and Skills (BIS) has been charged with ensuring that feedback gets to ministers so that they are fully informed. If the voice of UK science is not heard that will not be due to a failure of the structure: the fault will be ours for failing to engage. However, the sheer number of stakeholder groups across Europe, each wanting its own voice to be heard, militates against effective decision-making.

This landscape, alongside that for joint funding, must be improved. The European Science Foundation and the European Heads of Research Councils (EUROHORCs), is likely to be replaced by a new body promoting the collective interest of both research-funding and research-performing organisations. It will support member organisations in fostering European research and strengthen the European Research Area through direct engagement with key partners. The new body will provide a point of contact and engagement to ensure that the grand plans in the 2020 Strategy and the European Research Area are brought to fruition.

UK universities and Europe

For research-intensive UK universities this is a major opportunity. The aspiration to increase the number of people with tertiary qualifications can only improve the workforce. We are likely to have a differentiation across Europe between universities which are research-led and others that will concentrate on training. The UK must take a positive stance: we are capable of leadership in this area and we should seek that role.

We must participate in the groups that have been created to develop the agenda. At individual and group levels we need to identify the right partnerships within the EU. An ever-greater fraction of our young post-docs is looking to partner with the EU. We need to set the foundations upon which such collaborations can really flourish.

This is an opportunity: let us engage and participate. □

Europe 2020. http://ec.europa.eu/europe2020/index_en.htm

A view from France

Bernard Belloc

The European Research Area has been in existence for a decade now, but we have to ask continually how we can build ever-stronger scientific partnerships in Europe. The funding models for research across Europe can be very different, yet they must be able to work together if European research partnerships are to develop their full potential.

In the French system there are universities, *Grandes Écoles* and scientific institutions. We separate education in the universities from research in the scientific institutions. Between the two lie the *Grandes Écoles* which are outside the system, although a number of them undertake significant scientific activity.

President Sarkozy has long been convinced of the need to modernise the universities and the first step is to give them autonomy. In France, 95 per cent of university budgets come direct from the state. The academic programmes are decided in the ministry of higher education.

So in August 2007 universities were granted autonomy – in recruitment, in managing their budgets, in diversifying resources. This reform was primarily to allow diversification. Every country needs universities which specialise in research and others that focus more on professional training, education, etc. Our universities now have the autonomy to find this diversity.

The funding system is also changing from one based purely on the number of students to one where part of the money is dependent on the quality of the faculty and its research. There has traditionally been no selection for university – anyone with a baccalaureate is entitled to go – but each year, approximately 55 per cent of those young people achieving the baccalaureate prepare for studies at selective institutions like the *Grandes Écoles*, *Insituts Universitaires de Technologie* (which are integrated with universities) and *Sections de Techniciens Supérieurs* (which are parts of Lycées), etc. Some universities in France are beginning to select at the commencement of first degree courses by creating new, more elitist degrees: bi-disciplinary licentiates.

Professor Bernard Belloc is Higher Education and Research Adviser to the President of France. He is a Professor of Economics at the University of Toulouse, with doctorates in both economics and mathematics applied to economics.

The French government is introducing incentives to improve the research interface between scientific institutions and the best universities. New funding agencies are being created which will award money on a competitive basis.

There are now tax incentives for private business investing in innovation and research to the tune of a 30 per cent reduction for investments of more than €100 million. So the landscape is changing in France.

Europe produces the greatest number of science and engineering graduates in the world, far more than the USA or China, for example. Within Europe, the UK and France have the highest numbers. In terms of published scientific articles, 30-35 per cent of the world total comes from Europe.

So the programme for Europe is not to improve the level of academic research. The problem is a lack of competitiveness with the emerging countries. That is why we need to develop strong scientific partnerships – it is not only to increase the level of European research but to link scientific and economic activity. Of course, basic research is not directly linked to economic applications, but we need to improve the way academic research is transformed into innovation. If we fail in this objective, then in less than 10 or 15 years we will be second rate.

In Europe only 15 per cent of R&D expenditure is coordinated by Europe. The major funding for R&D, more than 60 per cent, comes from individual countries – the UK, France, Germany and two or three other countries. So we need to improve the coordination between different countries. To win a competition you need to enter the best competitors. In this context that means the countries with the best scientific abilities. More direct coordination is needed at country-to-country level in order to develop successful scientific partnerships in Europe.

Joint programming as envisaged by the European Commission may be a very good thing, but we also need more joint programmes between nations in Europe.

I am not convinced that the European scientific research area is the correct focus for investment. I believe that a European innovation area would be more appropriate. Europe needs to be more attractive to young, innovative companies and the young researchers who want to create their own companies. We need an area in which it is possible to transform research in economic activities. We need to develop scientific cooperation inside Europe but the first objective should be to develop a European innovation area. □

French National Research and Innovation Strategy. www.ambafrance-uk.org/National-Research-and-Innovation.html

Building stronger European research partnerships

Citizens increasingly expect science and technology to contribute to solutions to the challenges society faces. To meet this expectation, Europe needs to respond effectively to key current trends in research and innovation.

With the globalisation of knowledge; countries like China are no longer followers, they are leaders. The USA and Japan have responded by putting in place strategic initiatives to deal with the situation – Europe needs to do the same.

The fragmented way in which research is currently organised in Europe must be addressed urgently. The EU's share of global knowledge production has declined over the last 15 years. In the EU, there is little increase in business R&D investment, while countries like China, South Korea and even Japan are moving well ahead.

To improve this situation, Europe must develop world-class excellence in critical areas. It needs to organise its research funding more efficiently and make investment easier. It must also engage in strategic cooperation with partners around the world.

The financial crisis has cost the EU €1,000 billion and six million jobs. Yet if we invested 3 per cent of GDP in R&D – our current objective – we could create 3.5 million jobs and generate close to €800 billion in revenue by the year 2025.

Public research programmes have, in the past, addressed major societal challenges effectively. Examples include the green revolution, which stopped famine in the world, and the development of penicillin. In Europe today, public research is not fully realising its potential contribution to addressing societal challenges because its funding is overly compartmentalised. When spending across the 27 countries is combined with expenditure at EU level, Europe is quite close to the level of the USA and well ahead of Japan and China. However, in Europe only 10-15 per cent of public research spending is carried out on a trans-national, collaborative basis. In the USA, 85-90 per cent of funding is given on a competitive, federal basis.

In the EU, the way our public research funding is channelled is changing. Member States are increasingly collaborating in areas where R&D has a key role to play in addressing the challenges facing Europe.

That will not mean abandoning national research programmes, far from it. On their own, however, these are not sufficient to address major global societal challenges. Over the last 50 years we have seen increasingly successful cooperation at European level. To achieve the necessary scale and depth to meet the new challenges, a step change is now required, involving a genuine partnership between EU Member States. One way to catalyse this at European level is through joint programming of research.

Seán O'Reagain is Acting Head of Unit, Coordination of National Research Programmes - Joint Programming and Major European Initiatives, in the Directorate-General for Research of the European Commission. He has previously been responsible for European Technology Platforms and for the action plan on the 3 per cent objective for research investment in Europe.

Joint programming

Through joint programming, Member States come together on a voluntary basis to define and implement strategic research agendas, based on common visions for tackling societal challenges. Such an approach does not involve asking for more money from Member States or transferring funds from national programmes. It is not about asking for more power at EU level to influence national research programmes and it does not involve a new instrument for EU research.

Rather, joint programming is a process. It involves putting together resources, using the most appropriate instruments – be they at regional, national or European level – and then, collectively, monitoring them to ensure that progress has been achieved.

Critical to the success of joint programming is top-level political endorsement. The process works, essentially, in three stages. First, high-level representatives, nominated by the EU Council of Research Ministers, identify areas for joint programming. Second, they make recommendations to ministers who endorse proposals for particular areas. A steering group of Member States' experts then oversees the implementation of each initiative.

Implementation is also a three step process. Experts identify a common vision and set out clear, long-term objectives and deliverables. These are translated into a common strategic research agenda with measurable indicators, based on a clear assessment of where Europe wants to go and how best it can use its collective abilities. Executing the strategic research agenda involves choosing the most appropriate instruments and putting them together in the most effective way. It also involves regular monitoring and reporting to ministers.

Identifiable benefits

So far, 10 areas have been identified for joint programming. The pilot initiative relates to 'neurodegenerative diseases, including Alzheimer's'. This has brought identifiable benefits, such as the joint UK-German initiative, involving Canada in establishing centres of excellence. It has brought other European countries into the process. Another early example of progress is the initiative on 'agriculture, food security and climate change': 20 countries have already put money into a common pot in order to launch the initiative. First initiatives such as these will form a test-bed for joint programming.

Joint Programming is still in its early stages but there are potentially great benefits from a number of Member States coming together to develop common solutions. For example, smaller countries which, because of high start-up costs, do not have a tradition of ambitious research programmes may benefit particularly through becoming involved. Most importantly, Joint Programming should contribute to the elimination of undesirable duplication across national programmes.

The scientific community can expect greater mobility and increased impact by sharing information and working with colleagues across the EU.

Business will also see benefits and opportunities arising from more open innovation strategies; more rapid dissemination of research results; development of common, standardised solutions across a number of countries at European level; and better access to public research support. □

The views expressed are purely those of the author and may not in any circumstances be regarded as stating an official position of the European Commission.

Can a change in consumer behaviour towards energy usage help the UK achieve its carbon reduction targets? The question was discussed at a meeting of the Foundation for Science and Technology on 24 November 2010.

Modelling pathways to greener energy supplies

David MacKay

I consider myself a 'green' of long standing. Yet a few years ago, when asked how much energy I used at home, I realised that I did not know. So I began to read the meters on a regular basis and it changed my life. I turned the thermostat down to 17°C and then 13°C. Often 13°C feels fine, but sometimes it feels chilly. A simple target temperature was not enough, but by juggling with the thermostat up and down I was able to virtually halve my gas consumption. I switched to low-energy light bulbs and always switch off the DVD player after watching a DVD. I have made significant changes at home. Behavioural change is possible, but can we engage the public at large in the same sort of meter-reading activities?

The Department of Energy and Climate Change has developed the 2050 Pathways Calculator, to be found on the DECC website. This allows users to experiment with both the supply side and the demand side of the energy-use equation. It also helps users to assess the lifestyle choices that determine the energy we consume as individuals.

Pathway Alpha

To understand how the calculator works, a good starting point is to look at Pathway Alpha . This is a combination of demand-side and supply-side choices that achieves the goal of an 80 per cent reduction in greenhouse emissions by 2050. The lights stay on, so to speak, while still satisfying supply constraints even when there is no wind for five days.

There is a 'central pathway', one of the options found with this tool that achieves both security of supply and emissions reductions. It is central in that it involves strong effort in all sectors: by making a stronger effort in specific demand- or supply-side areas and less in others, a range of other viable pathways can be obtained. For instance, people looking for a cost-optimal solution can direct the model in that direction while those who want to minimise environmental impacts can adapt the model in a different way.

Professor David MacKay FRS is Chief Scientific Adviser at the Department of Energy and Climate Change (DECC) and is a professor in the physics department, the Cavendish Laboratory, University of Cambridge. He did his doctorate at Caltech where he was a founder member of the Caltech Environmental Task Force. He has published a popular book on energy supply and demand, *Sustainable Energy – Without the Hot Air*.

On the demand side, one can introduce more cycling and public transport. Alternatively, the use of electric vehicles, which are more efficient than conventional ones, can be increased provided there is an efficient way to deliver the electricity and to cope with the increased electricity demand.

The base model for Pathway Alpha includes a significant amount of electrification of transport.

The photovoltaic systems in Pathway Alpha would involve a 4,000-fold increase over today's levels, which could be achieved with 34 million rooftop systems of 10 square metres each. In fact, Britain does not have 34 million homes, so this solution would actually require not only rooftop systems but also the Bavarian method of covering the countryside with solar plants, too!

The contribution on the hot water side – 19TWh per year — would come from 14 million rooftop systems, each 3 square metres in size. The heat pumps delivering 234TWh per year would require 20 million pumps, replacing condensing boilers in many buildings. The Japanese have proved to be very successful at deploying such heat pumps: we could learn from their experience.

As for biomass, Pathway Alpha includes two elements. 'Import' corresponds to an area half the size of Wales in another country delivering biomass in some form. The term 'biomass' itself refers to an area one and a half times the size of Wales here in the UK being used for production of biocrops and forestry.

On the waste-to-energy front, we would need a thousand towns (effectively all the towns in Britain) each having a facility to take 300 tonnes per day of municipal, commercial, industrial and agricultural waste. That total amount of waste is roughly three times today's municipal waste production.

On the nuclear front, Pathway Alpha supposes a resource equivalent to building 39 Sizewell Bs, a four-fold increase over today's level. It can be achieved if we can follow France's approach: they have the equivalent of 63 Sizewell Bs built in a couple of decades.

40GW of coal, gas or biomass power stations with carbon capture and storage (CCS) is the final supply-side contribution in Pathway Alpha. The mass flowrate of carbon dioxide into the North Sea from these power stations would be the same as the peak mass flowrate of oil extracted from the North Sea in the past few decades. It is probably practicable, but a great challenge.

Matching supply and demand

Pathway Alpha requires supply to match demand at all times, so it envisages more storage, greater inter-connection to other countries to help with balancing and a lot of smart demand management — for instance moving the times at which electric vehicles are charged and heat pumps operate in order to balance supply and demand.

One option that Pathway Alpha does not use is the import of electricity from other countries. The 2050 calculator does include it, so it can be used instead of some of the other sources.

The whole 2050 Calculator spreadsheet is available as open-source software. Users can scrutinise it and help improve this tool. This should encourage constructive conversations examining the trade-offs between lifestyle changes, technology switches and different supply side options. The aim is that those conversations may lead to lifestyle change and, indeed, to people pressing for legislation and measures that cause lifestyle change through other mechanisms such as marketing. □

Carbon calculator. http://2050-calculator-tool.decc.gov.uk

Delivering the UK's low-carbon targets

Stuart Groves

The UK Government is committed to delivering two major, low-carbon targets by 2020. The first requires the UK to reduce carbon emissions by 34 per cent relative to 1990 levels. The second requires the UK to source 15 per cent of its energy from renewables.

Clean energy survey insights

In late 2010, Booz & Company and 2degrees (an online community of clean energy experts) conducted a survey about the UK's 2020 low-carbon targets. The majority of experts surveyed believed the UK would not meet the 2020 targets: over 25 per cent thought the targets would not be achieved until 2030. All survey participants identified the reduction in energy demand as a critical lever in the delivery of the targets. In addition, many participants agreed that a shift to renewable electricity and nuclear power would also be required.

Finance for generation and infrastructure capital projects was considered the most critical barrier to delivery. The next three barriers relate to demand side/consumer issues: insufficient financial incentives to promote investment in domestic low-carbon and renewable technologies; inadequate incentives for demand reduction; and limited consumer interest and awareness. Interestingly, most respondents believed we do not have technology limitations.

No 'silver bullet' activity was identified that would ensure delivery. Policies to support demand reduction were considered important, but there was limited consensus on other potential levers.

Booz & Company has also independently assessed the UK's likelihood of meeting its 2020 targets, the barriers to implementation, and priority actions to support delivery. We analysed these questions from both supply (low-carbon generation and renewable heat) and demand (buildings, industry and transport sectors) perspectives.

Stuart Groves, a Principal at Booz & Company, specialises in strategy, operations and performance improvement in the low-carbon, renewables and broader energy sector. He started his career in low-carbon in 1995, working for Ballard Power Systems on the development of fuel-cell technology for automotive applications.

2020 delivery and key barriers

Overall, the 2020 targets can be achieved but there is a high risk of failure due to the many implementation challenges. To help reach these targets, we believe there must be a significant deployment of low-carbon and renewable technologies in the electricity generation sector. Today, there are many onshore/offshore wind and biomass projects in the planning and concept phases that will be financially attractive, assuming sufficient Government incentives are implemented. If the vast majority of these projects are completed, we believe the UK can get close to 30 per cent renewable electricity generation by 2020.

However, the challenges and uncertainties related to the deployment of renewable *heat* are much greater. Many of the key technologies (e.g. air and ground source heat pumps) are too expensive for consumers relative to conventional technologies. In addition, they have poor supply chains and unclear performance levels.

Current trends suggest that, without intervention, there will be limited carbon reduction from demand and efficiency improvements; indeed there may even be an increase in the short term as the economy emerges from recession. However, we believe there is significant scope in the buildings, industry and surface transport sectors since there are a number of opportunities to expand the implementation of low-carbon technologies and reduce energy consumption. In many cases, this will require dramatic behavioural changes.

Priority actions

There is no one action that will ensure delivery of the targets – the sectors are too broad, the technologies too specific and the barriers too diverse. However, we have attempted to identify priority actions for Government, communities, businesses, and consumers.

On the supply side, there is a clear need for massive investment in electricity infrastructure to support the delivery of offshore/onshore wind and nuclear power. In particular, additional transmission infrastructure will be required.

As a second priority, additional financial incentives are required to drive investment in renewable generation capacity. Today, the carbon price (i.e. what has to be paid for the emission of one tonne of CO_2) is too low to stimulate significant investment. Furthermore, the low-carbon regulatory framework is unclear post-2014. Significant reform has been proposed by the UK Government's Energy Market Review, including a Contract for Difference or Premium Feed-In-Tariff to incentivise low-carbon generation. Such reform is required and, crucially, it must be implemented with speed to prevent a hiatus in investment. In addition, careful consideration must be given to ensuring that the level of incentive within the proposed regulatory mechanism is adequate to make low-carbon projects attractive to investors.

A third priority is to implement improvements in the planning and permitting process for infrastructure and generation capacity. We must consider the speed, efficiency and cost of this as it is a bottleneck for many projects. It would be useful to have increased clarity about the role of the Major Infrastructure Planning Unit, which will replace the Infrastructure Planning Commission (IPC) and should

play a key role in expediting the start of key construction projects.

On the demand side, as a priority, we must focus on changing consumer behaviours. Research suggests that understanding personal energy usage can change overall consumption patterns. Smart meter roll-out with personalised information on energy consumption is one of the most important levers. Product labelling (e.g. energy efficiency levels) and increased education programmes – about both impacts and opportunities to reduce consumption – will have a part to play. Continued support for community action on climate change is also important for driving consumer change at the local level.

Increased funding is required for renewables and efficiency technologies. In particular, there is an important role for schemes which reduce the need for consumers to pay the upfront capital of investing in energy efficiency – and allow payments to be made as savings are realised (known as pay-as-you-save schemes). The UK Government must clarify the domestic funding arrangements and delivery model for the proposed Green Deal and Renewable Heat Incentive schemes. In addition, more funds must be made available to small and medium enterprises which currently have limited access to finance for energy efficiency investments.

Finally, more stringent regulation and standards for buildings, electric appliances and vehicles will also support emission reductions. For example, by raising the performance standards for the worst non-domestic buildings we could save up to 15 per cent of emissions in this sector. ☐

Encouraging changes in consumer consumption patterns

Pilgrim Beart

AlertMe uses modern technology to give consumers visibility and control of their energy consumption. This has provided some experience with real consumers who are considering how they might change their lives in order to change their energy consumption.

The power required to run our nation is about 300GW on average — about 5kW per capita — and 30 per cent of this is consumed in our homes. Add to this the 17 per cent consumed in our cars, and nearly half of all UK energy is used directly by individuals. We do this largely from a position of ignorance: the way we consume energy today has been compared to shopping in a supermarket with no prices on the shelves, then receiving an un-itemised bill a few months later. We can see that it is expensive, but there is no easy way to work out why.

The strongest motivator

Money is the strongest motivator in reducing consumer consumption. Whatever the policy framework, the price of home energy ought to increase, or at least stay high, in order to reflect the true value — and cost — of using up our society's natural capital. Energy bills hover at about 9 per cent of disposable income today, and householders are concerned about them. However, we must move away from today's tiered pricing model: this encourages profligate use since under this scheme energy becomes cheaper the more you use.

As social animals, people compete to be better than others, while they also love to collaborate as part of a team. How can these drives be harnessed to motivate energy reduction behaviour? Here are a few ideas. We can ask: "If your home consuming more energy than your neighbour's?", "Is your town doing better than the next town?" Peer pressure can be a powerful driver.

Pilgrim Beart is Founder and Director of AlertMe, a Cambridge start-up company specialising in energy and security monitoring products. After six years working in Silicon Valley in the 1990s for companies like Atari and Chromatic Research (now AMD), he returned to Cambridge UK where, prior to AlertMe, he founded two other companies: activeRF Ltd and Antenova Ltd.

Most consumers believe the size of their energy bills to be beyond their control. That perception must be changed by improving consumption information, ideally giving feedback on the cost-per-use of appliances (including heating) at the time they commit to each energy expenditure.

While today's in-home displays give a view of how much *power* is being drawn right now – in kilowatts – the bill relates to total *energy* consumption – in kilowatt-hours. The technology is now available to automatically disaggregate household consumption, breaking it down to show consumers the contribution of major appliances to their energy bill.

Empowering consumers

When considering how to motivate and empower consumers, some segments are harder than others to empower. For example, nearly seven million people in the UK are functionally innumerate. They cannot easily understand numerical displays, but a speedometer-style dial or coloured warning light makes power easier to understand, for example: green for normal conditions when at home, red when the tumble-dryer is running, and blue when you are going out, or in bed. Unless the display is blue, something has been left on. It works for everyone, because it acts subliminally, making people aware of energy use without claiming too much attention.

False economies should be made more obvious. The rental cost of a washing machine with A-class efficiency can be twice as high as renting a C-class machine. Yet renting the A-class can be cheaper overall due to its lower running costs. Energy labels are a start, but better explanations are needed about why it matters, and ideally numbers should be given in currency rather than abstract scales.

People can be helped to budget effectively. Many have prepay meters, and the consequence of poor budgeting is to be temporarily cut-off. By helping track consumption through a day, week or month, people can be helped to take early action and get their consumption back on track.

In some areas, consumers have already embraced sustainability, even to their short-term inconvenience or cost. Examples include energy-saving light bulbs and recycling. What lessons from these successes can be applied more generally to home energy reduction? First, visibility: you can see a light bulb or recycled materials but you cannot see heat escaping through the roof or fuel being burned. Second, convenience: many people will contribute to the public good if it is convenient enough. The consumer aspects of the Government's Green Investment Bank, announced in October 2010, seem rightly focused on convenience.

It is vital to communicate well, explaining before exhorting or compelling, especially since energy-saving happens inside the home. The new Annual Energy Statements, showing everyone the total annual cost of their energy – £1,200 on average – should provide not just clarity, but also stimulate 'bill shock'.

Delivering change

How can change be delivered? The main players are Government, business and the consumer. A Government-only approach could be characterised as 'forcing it through': taxing energy highly, rolling out smart meters without consultation, forcing people to insulate their homes, perhaps even enforcing personal carbon rationing. This is probably not a vote-winner. Smart meter rollout in the Netherlands has been stopped in its tracks by consumer concerns over privacy.

It could be left to business, including the utilities. But utilities make their money by selling energy, and experience tells us that deployments planned by utilities for the benefit of utilities run into strong resistance from consumers.

The third option, simply leaving the consumer to make the right choices, is also unlikely to work in isolation. Consumers can only make choices they are offered, so there would not be sufficient empowerment. The consumer must be at the heart of everything, although Government and business are also needed to deliver choice.

The Government's role is to establish the facts and make key decisions, with a focus on empowering all the players. An important element of this is outreach to consumers. Pushed by Government and pulled by consumers, enlightened utilities are already transitioning from low-margin energy retailers to providers of high-margin energy services. The power of 'consumer pull' can be seen in, for example, the mobile phone market. If consumers are provided with the tools to take full advantage of smart meters, so that they actively want them, the UK could become a leader of free-market innovation in consumer energy.

Past successful sustainability initiatives such as low-energy light bulbs have gone through a three stage process: 'enable it, socialise it, enforce it'. Business made the bulbs available, consumers got used to them, Government outlawed incandescent filament bulbs.

The US company Comverge helped utilities avoid building new power stations with its demand-response programme, adjusting millions of consumer thermostats remotely during peak grid demand. Something like this will happen here, although I hope that we adopt a less prescriptive, more price-driven model. Paying consumers to make their consumption more adaptable is worth doing.

One important trend is selling services rather than just products. Services outsource the management responsibility, and lead to savings because they push the operational costs onto the service provider, who is then strongly motivated to minimise them. Service industries have a track record of doing more with less, reducing energy consumption per unit of output by 40 per cent over the past few decades.

Factories can pay their utility for delivering a temperature on the shop floor. This is an example of an ESCO – an energy services company. It should be possible to translate this to the consumer realm: provide a level of service for a fixed fee and share the benefits of efficiency improvements.

Are personal carbon targets likely to be tomorrow's reality? Is it already possible to participate in personal carbon trading at *myemissionsexchange.com*. The Isle of Eigg recently worked out that capping energy demand for individual homes to 5kW would halve the need for renewables. That's how Italy works already, using only 3kW or 6kW connections to the grid compared to the UK's effectively unlimited 18kW.

The consumer perspective

What would the transition look like from a consumer perspective? In recycling, we have the mantra of reduce, renew, recycle. The equivalent transition for home energy could be reveal, reduce, renew.

In the reveal stage, in-home displays make consumption visible, and annual bills provide the 'shock' to overcome inertia. An early response is to switch providers, but as the benefits of this become marginal due to competition, suppliers will increasingly need to really differentiate; one way they will do so is by offering added-value energy services.

The reduce stage is a series of behavioural changes and purchasing decisions, reducing consumption. The renew stage is reached once much of the waste has been eliminated. Then the next big gain will come from local renewables. All of this could result in energy bills falling, even when prices are rising.

UK energy consumption today is wasteful. However the cheapest watt is the one that does not have to generated in the first place: the 'negawatt'. Reducing demand can be cheaper and quicker than building the equivalent renewable supply. Although we need to switch to energy from renewables, reducing consumption is essential to reduce the capacity that needs to be built.

The UK needs a set of well-designed solutions, targeting every worthwhile saving. There is huge potential to reduce energy consumption by unleashing frustrated consumer engagement, without affecting our quality of life. Actions that we take now could deliver significant, measurable difference within this Parliament. ☐

DISCUSSION

Global perspectives

Carbon emissions reduction is a global issue, not just one for the UK. A number of countries – the United States included – are retreating from green programmes, concerned at rising costs and the possibility that their industries will become uncompetitive. The same could happen here. The Royal Commission on the Environment has expressed concern that while all sources of energy have environmental objections, it is important not to be negative but to create a consensus in which environmental and energy projects are considered together. The issue is really one of risk avoidance. Fossil fuel prices may well soar in future. Does business understand that without innovation and meeting environmental concerns, they might find themselves in decline?

In the coming decades, by far the larger part of humanity will live in cities. How can these conurbations be made sustainable? That was the question addressed at a meeting of the Foundation for Science and Technology held at Newcastle University on 10 February 2011.

Making old industrial cities sustainable

Paul Younger

More and more of the world's population is living in cities, and this process is not about to reverse. Most of the future growth of urban population will be in *existing* cities. Accordingly, the much-publicised new-build 'eco-cities' such as Dongtan (near Shanghai, China) and Masdar City (Abu Dhabi) are of limited value in helping us learn how to achieve 'sustainable urbanism'. The real challenge is to achieve sustainability in old industrial cities: retro-fitting sustainability in cities with large inheritances of low-performance infrastructure (transport, energy, water, waste, etc).

The term 'sustainable urbanism' is subject to conflicting definitions. Some emphasise urban *form*, e.g. "Walkable and transit-served urbanism integrated with high performance buildings and high-performance infrastructure"[1]. Others emphasise *process*, e.g. "Application of public health and societal ethics in places"[2].

Neither of these definitions is particularly satisfactory, as each fails to engage directly with the natural environment. To develop a more holistic definition of 'sustainable urbanism', it is first important to be clear what we mean by 'sustainability'. In Newcastle, we have adopted the following definition of sustainability: *Enough, for all, forever*.

By 'enough' we mean economic sufficiency (but *not* damaging excess); in saying 'for all' we invoke not only social justice, but also the needs of non-human beings. Committing to anything 'forever' demands that we respect the finite nature of natural resources (renewable and non-renewable) and commit ourselves to pursuing inter-generational justice.

From this definition of sustainability, we can derive the following definition of 'sustainable urbanism':

Urban planning, policy and practice that seeks to achieve socio-economic and environmental justice, now and in the future.

Coals to Newcastle

There are few places that better fit the description of an old industrial city than Newcastle upon Tyne, the city that gave the world 'carboniferous capitalism' when it began mining coal at an industrial scale in the late 16th century.

Professor Paul Younger FREng DL is Director of the Newcastle Institute for Research on Sustainability (NIReS) at Newcastle University. His background is in hydrogeology and environmental engineering, with a focus on empowering communities to tackle post-industrial pollution, the provision of clean water and the development of geothermal energy. He is a Fellow of the Royal Academy of Engineering and was appointed a Deputy Lieutenant for the County of Tyne and Wear in October 2009.

Four centuries later, Newcastle has been independently identified as the most sustainable of the UK's 20 largest cities for two years in succession (2009, 2010) by the thinktank Forum for the Future. To sustain the momentum, the municipal authorities of Newcastle and neighbouring Gateshead have developed a joint economic and spatial strategy, called the '1Plan', which sets forth a 20-year vision for NewcastleGateshead to "become a great northern European city, transforming the urban core through sustainable urbanism".

This will require substantial expansion of the science- and engineering-based knowledge economy in NewcastleGateshead, drawing on the activities of Newcastle University and other FE and HE institutions. The Newcastle Institute for Research on Sustainability (NIReS) was established to draw together the expertise of hundreds of researchers and provide the university partner for the City Council in the Newcastle Science City initiative.

Newcastle University has long been active in urban sustainability research initiatives. Currently, these include:

- leading the Cities programme of the Tyndall Centre for Climate Change Research, focusing on how cities can grow without increased emissions or vulnerability to climate change;
- the EU FP7 project Sustainable Urban Metabolism for Europe, which seeks to establish more sustainable planning strategies over the next four decades;
- the Newcastle CarbonRouteMap: a rigorous urban energy and CO_2 emissions analysis approach, developing spatially-referenced area-based tools to help local government make the economic case for retro-fitting low-carbon interventions;
- electric vehicles: Nissan, Smith and other companies in the North East are at the forefront of this technology. Newcastle University is involved in monitoring trials of vehicles in NewcastleGateshead, and in developing light, tank-free, lithium-battery engine systems, taking oxygen direct from the air by filtration (instead of storing it in onboard tanks);
- offshore wind: the Dogger Bank lies 100km due east of Tynemouth and development there is stimulating major investment in assembly and manufacture, as well as support facilities, on the Tyne. Newcastle University is leading innovation in the design of marine structures, turbine gears and seabed HVDC transmission technologies;
- deep geothermal energy: with financial support from DECC's Deep Geothermal Challenge Fund, drilling has commenced on a 2km-deep borehole on the Science Central site, the first step in creating a 24-acre City Centre science park and sustainable urban living zone. This will be one of the principal outcomes of the Newcastle Science City initiative.

The sustainable construction of Science Central over the next 15 years or so is one of the earliest elements of a wider initiative to treat the entire NewcastleGateshead conurbation as a living laboratory of sustainable urbanism, re-developing it as a global exemplar of best practice. This is not just about technology: mechanisms to increase participation in decision-

making are equally important. Nor is it just about the City: we must address the interactions with the rural North and the wider world from which we draw resources.

Challenges

Is the pursuit of such a vision hubristic in an age of austerity? There is no doubt that public investment can help reduce the risk of innovative developments and make them more attractive to private investors. Nevertheless, little that has been achieved so far in the North East is solely due to direct public funding – much more has come from private investment. Even more important has been public partnership, aligning spending which would have been incurred by different partners anyway. Maintaining and expanding partnerships is the key to realising the 1Plan.

More generally, sustainable urban development options tend to be cheaper than conventional ones when whole life-cycle costs are taken into account. However, they can appear more expensive where one party pays for capital expenditure and another for operating expenditure – especially where private investors seek unreasonably short payback periods. Traditionally, this has been addressed by trying to get the public purse to pay for the perceived 'sustainability mark-up' in capex, allowing others to reap disproportionate benefits in reduced opex. Maximising sustainability will require a more grown-up approach to project funding.

There are also other challenges which must be addressed as we pursue sustainable urbanism. For example, is it realistic to think we can prioritise development on the basis of sufficiency rather than the habitual pursuit of excess? Or again, given the particular severity of the public spending cuts in the North East, will this eliminate the scope for public spending to lever-in high rates of private investment at levels previously achieved in Newcastle Gateshead? □

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Sustainability: what we do and how we do it

Peter White

There is clearly a need for Government action and public sector stimulus in order to put the UK onto a more sustainable trajectory and meet its goals for climate change. The most important role for Government, however, is to set the right long-term vision and policy frameworks, within which the private sector can unleash the power of sustainable innovation.

Even within current frameworks, there is much that business can do to "improve quality of life for everyone – now and for generations to come" (the original UK government definition of sustainable development). Addressing sustainability is in the long term self-interest of business and – because much of environmental sustainability is about reducing waste and increasing efficiency – also has direct short-term benefit too.

By considering three specific factors, companies may find it easier to benefit from implementing sustainability programmes.

- Take a broad approach to sustainability, including social and economic as well as environmental aspects. Focusing just on the environment often excludes opportunities to improve lives in the social dimension, which can themselves be business opportunities. Failure to address the economic aspects means companies will not be there in the future to deliver the social and environmental benefits!
- Look at *what* a company does, as well as how it does it. Many companies focus on the 'how' – they try to be more efficient and more responsible in their operations. While this is important, it is also critical to look at the value delivered to society through the products and services a company provides. Businesses that think this way end up incorporating sustainability into almost every part of their operations.
- Link opportunity with responsibility. Responsibility is often about minimising impacts and being 'less bad', but sustainability offers the opportunity to do positive good and build business at the same time.

Dr Peter White is Director for Global Sustainability at Procter & Gamble and Visiting Professor at the Institute for Research on Sustainability at Newcastle University. He helped found P&G's Sustainable Development organisation in 1999, and in 2007 created and led P&G's Sustainability Leadership Council. Peter was an architect of P&G's long-term Sustainability Vision and 2020 Goals announced in September 2010. He also leads P&G's Global Sustainability Department.

Businesses can make major contributions to a more sustainable society if they know where their impacts occur, understand their consumers, promote innovation and industrial ecology, and use their core strengths to address the most pressing sustainability challenges.

Know where the impacts are

For any business to become more sustainable, it needs to understand where its major impacts occur, and where it has the biggest opportunity for improvements. This should be done over the full life cycle of the products or services that the company provides, and may lead to unexpected results. Some 10 years ago, P&G used Life Cycle Assessment (LCA) to complete an energy footprint for the company, involving all the stages of its key product categories. The result showed that most energy use (and hence CO_2 emissions) was not associated with manufacturing plants, but with heating water in consumers' homes to wash clothes.

This led to a programme of product innovation to develop detergents that work effectively at low temperature – initially at 30°C with Ariel CoolClean and then as low as 15°C with Ariel Excel Gel. The opportunities from cold water washing are significant, since in the UK it can save 40-50 per cent of the energy per wash. If everyone in the USA were to wash clothes in cold water it would save about 3 per cent of their total domestic energy consumption, and deliver over 6 per cent of their original Kyoto commitment for greenhouse gas reductions.

Understand the consumer

Technological innovation is vital, but only

DISCUSSION

Behaviour and aspirations

Changing people's behaviour and aspirations is the key to reducing demand for energy and other resources. Three major elements were identified, all of which were interlinked: information or communication; social cohesion and influence; and regulatory pressure. For all of these elements partnership between public authorities, universities, and private industry is vital.

part of the story. Unless consumers adopt new technologies, and change behaviour accordingly, sustainability benefits may not be delivered. Developing a detergent that cleans brilliantly at low temperature is no benefit unless consumers actually select low temperature wash programs – hence the importance of campaigns like Ariel's Turn-to-30, aimed at changing consumer behaviour.

Insight into consumer needs and behaviour is key to successfully influencing behaviour. Consumer studies from around the world show remarkably similar results about how consumers choose and use products. In Europe, the USA and Japan, only around 15 per cent of consumers (the 'green niche') will accept a compromise in terms of performance or value for the sake of a more environmentally sustainable product. At the other end of the spectrum, around 15 per cent of consumers are too concerned with basic living to consider sustainability attributes.

In the middle, however, there is a large 'sustainable mainstream' (about 70 per cent of consumers) that will buy a more sustainable product, or adopt more sustainable behaviour, so long as they are not asked to make any trade-offs in performance or value. Most consumers, for example, will change their behaviour to low-temperature washing, but only if their clothes are cleaned as well as (if not better than) before, with no extra cost or inconvenience. With 'no trade-offs', there are wins for the consumer, the environment and also for the detergent company delivering the innovation.

Industrial ecology

Companies can also contribute to the sustainability of the cities and towns where they operate though improvements in the environmental performance of their operations. In particular, major businesses can set up networks in their supply chain to convert previous waste materials into resources – the concept of Industrial Ecology. Although P&G already converted 96 per cent of all materials entering P&G plants into packed product (with half of the remaining material recycled), the company set up a specific global programme to reduce solid waste going to disposal. By identifying all of the waste materials, and searching for alternative future uses, it has been possible to reduce the waste per unit of production by an additional 50 per cent in just three years.

The solutions have been varied and creative: waste vegetable oil from producing Pringles in Belgium is now sold for conversion into biodiesel; waste from paper plants in Mexico is used to make low-cost roofing tiles for local construction; skin cream waste in China is used to condition leather. These projects benefit local businesses, cut costs for P&G and improve overall environmental efficiency.

Innovation and social responsibility

Social responsibility is often the first area mentioned for corporate involvement in sustainability. Companies, large and small, and their employees, are important parts of the communities in which they operate. Business cannot succeed in a society that fails, so it is in the long-term interest of business to build economically strong, healthy and vibrant societies. Many do this by supporting education or the arts, and through the 'volunteering' efforts of their employees. P&G's programme, entitled *Live, Learn and Thrive*, aims to reach 300 million children worldwide through a range of partners and projects in order to promote health, education and skills for life.

Business can also play a broader role by applying its core strengths – innovation, scale and consumer insight – to address large sustainability challenges, including those encapsulated in the UN Millennium Development Goals. For example, over a billion people do not have access to clean drinking water, and deaths from water-borne diseases exceed those from HIV Aids and Malaria combined. By using a simple, cheap and robust technology developed in Newcastle upon Tyne, it has been possible for P&G and its partners to provide point-of-use water purification for both disaster relief and longer term sustainable water supply. Currently in over 60 countries, this programme (Children's Safe Drinking Water) has delivered over 3 billion litres of clean, safe water since 2004.

Conclusions

- Business has a major contribution to make in delivering more sustainable cities and communities;
- Sustainability is good business, not an added cost for business;
- Sustainability is about what a business does, as well as how it does it;
- Sustainable innovation is essential;
- Understanding how customers and consumers behave, and why, is vital. □

The challenge and opportunity of regeneration

Can cities move towards sustainable economies without stimulus? 'Can' is such a slippery word. In an infinite universe almost anything can happen. I am more interested in what will happen, particularly in Newcastle, the city in which I grew up.

My definition of a sustainable economy is one in which everyone in Newcastle has a good job without destroying the planet. There is no point in a sustainable city where people do not have jobs. So when I talk about sustainability I also mean regeneration.

Regeneration rarely happens by accident. We are all familiar with Newton's First Law of Motion: a body remains at rest, or if in motion continues to move in a straight line at a constant speed, unless acted upon by an external force. Given that we do not have a sustainable economy now, achieving it requires an external force.

Now the private sector can provide that. But right now, in the North East,

Chi Onwurah is MP for Newcastle upon Tyne Central. She is Shadow Minister for Innovation and Science. An electrical engineer by training, her career has involved working in a number of different countries. Prior to becoming an MP, Ms Onwurah was head of Telecoms Technology at Ofcom, the telecommunications regulator, with a focus on broadband provision.

I do not believe that it will. It cannot deliver the necessary change on its own. Looking around the world there are common themes to successful regeneration: a strong local authority with clear aims and objectives; and strategic investment from central and local Government.

The Norra Älvstranden area of Gothenburg, Sweden, has many similarities with Newcastle and Gateshead. Formerly the site of shipyards employing thousands, the industry went into decline in the 1970s. Unlike the UK, the Swedish Government avoided mass redundancies, implementing retraining and redeployment schemes, and investing in education and research facilities in the area.

From the beginning, local authorities, universities and leading companies collaborated to create a cluster of knowledge-intensive firms, along with the facilities and environment to help them flourish. This was all part of a wider strategy.

Economic development

Today, we need more economic development. More jobs in sustainable industries that have real value. Jobs for graduates, but also for apprentices. To grow, we need to rebalance our economy so that it is not reliant on one sector or region. Our worth comes from what we produce, so growth needs to come from new technologies. Advanced manufacturing is a platform from which we can grow our economy.

160 years ago, this city was leading the UK into the Industrial Revolution; it was one of the most innovative cities in the world. But in the 1970s and '80s our industrial base was destroyed. We lost a generation of manufacturing talent.

As any business technologist knows, skipping a generation means you lose profits and opportunities but it does not necessarily mean you are badly placed to profit from newer technologies. As an electrical engineer I spent three years in Nigeria helping to build a new GSM network. The first telecommunications revolution has passed the country by: in 2001 fixed penetration stood at just 1 per cent. Yet by the time we had achieved 10 per cent coverage with our mobile phone network, Nigeria had some of the most advanced mobile banking applications in the world.

My vision for Newcastle is a city of well-educated, highly-skilled people working in sustainable industries. That has to be the driving force behind regeneration. Newcastle already has the foundations on which to build. The city hosts the Government's Marine Management Organisation. Thanks in part to the University of Newcastle, the North East leads the UK in electric vehicles. This region has the greatest wind reserves in Europe – the National Renewable Energy Centre (Narec) in Blyth, founded and funded by One North East, is helping to support that industry. At the same time, the North East Process Industry Cluster (NEPIC) enables new, innovative businesses in green process industries to expand. The Newcastle Institute for Research on Sustainability demonstrates the university's commitment to a sustainable future. There is a great opportunity for Newcastle to become a leading city for renewable and sustainable technologies.

We all agree we need growth. We need it in advanced manufacturing to help rebalance the economy. We need growth in sustainable industries to help meet our emissions targets and save the planet. The question is – how? I think Government has a role in four main areas.

Competition

Within competitive markets there are many incentives to innovate and grow. Markets which do not yet exist are by their very nature not competitive. New and emerging industries do not have established supply chains, so smaller companies have more difficulty establishing themselves in the market. This is bad news for our renewable energy sector. Here I think Government has a duty to ensure a level playing field.

Yet the present Government does not seem to understand the competitive ecosystem for new industries. If reforms to the planning system and the removal of targets for wind-farm planning approvals go ahead, the UK will cede more ground to international competitors.

Infrastructure

Government also has a role in infrastructure provision. Small companies developing new markets may not have the time or resources to put in place vital infrastructure: a test bed for wind turbines for example, or the massive steel press that the new nuclear power industry needs.

The test facilities at Narec and NEPIC help small companies grow. Now is not the time to be cutting and abolishing them. And whilst the Technology Innovation Centres are certainly a good idea, hundreds of applications for six centres speaks of confusion not leadership. Transport links are also a key part of the necessary infrastructure, for example port improvements and high speed rail.

The Government's decision to push back universal broadband to 2015 certainly has implications for growth, as well as for rural economies.

Skills

I believe we need to prime the skills pump for new industries. Engineering UK's recent study concluded that under-19 participation in Further Education at all levels of engineering and manufacturing has fallen by a staggering 43.2 per cent in the last five years. We need more engineers and technologists, scientists and entrepreneurs if we are to move to a sustainable economy.

Abolishing the Education Maintenance Allowance and withdrawing 80 per cent of public funding from HE are not going to help us fill that skills gap. I fear we are in danger of losing our world-leading position in science and engineering as a result.

Finance

Finally, let us talk about money! Direct Government funding of R&D plays an important role in maintaining the science base. Large and innovative companies tell me they do their R&D in the UK because they can link to great public sector research institutions – our universities. The recent decision of Pfizer to pull out of the UK is very worrying. Is a lack of investment and vision making the UK less attractive?

Government can support innovation and the move to a sustainable economy by means other than direct finance – through tax incentives such as the R&D tax credit and the 'patent box' which reduces taxation on revenues from new patents. The current Government is continuing with the patent box policy, but its position on tax credits is unclear.

I am concerned that this indecisiveness is part of a wider incomprehension of the relationship between Government and growth. Uncertainty kills business more quickly than bad news – business can respond to difficult circumstances and in some cases even flourish, but uncertainty is arsenic for new business. ☐

Recent dinner/discussions organised by the Foundation for Science and Technology are listed below. Summaries of these and other events – as well as the presentations of the speakers – can be found on the Foundation website at: www.foundation.org.uk

Can the Further Education system deliver the skilled people the economy needs?

2 March 2011

Philip Greenish CBE, Chief Executive, The Royal Academy of Engineering
John Hayes MP, Minister of State for Further Education, Skills and Lifelong Learning, Department for Business, Innovation and Skills and Department for Education
Dr Claire Craig, Director of Skills, Department for Business, Innovation and Skills
Amarjit Basi, Principal and Chief Executive, Walsall College
Norman Pickavance, Group HR Director, Wm Morrisons

Can cities move to a sustainable economy without a public sector stimulus?

10 February 2011

Professor Paul Younger FREng, Director, Newcastle Institute for Research on Sustainability, Newcastle University
Dr Peter White, Director, Global Sustainability, Procter and Gamble
Chi Onwurah MP, MP for Newcastle Central

The allocation of science and research funding 2011-12 to 2014-15

2 February 2011

Sir Adrian Smith FRS, Director General, Knowledge and Innovation, Department for Business, Innovation and Skills
Professor Malcolm Grant CBE, President and Provost, University College London
Dr Patrick Vallance FRCP FMedSci, Senior Vice President, Medicines Discovery and Development, GlaxoSmithKline

The wonder of the Web

8 December 2010

Professor Nigel Shadbolt FREng, Professor of Artificial Intelligence, School of Electronics and Computer Science, Southampton University

Changing behaviour — can a cultural shift be achieved in how people use energy?

24 November 2010

Professor David MacKay FRS, Chief Scientific Adviser, Department of Energy and Climate Change
Stuart Groves, Principal, Booz & Company
Pilgrim Beart, Founder and Director, AlertMe

Building stronger European research partnerships

17 November 2010

Sir Leszek Borysiewicz FRS FRCP FMedSci, Vice-Chancellor, University of Cambridge
Professor Bernard Belloc, Higher Education and Research Adviser to the President of France
Seán O'Reagain, Acting Head of Unit, Coordination of National Research Programmes – Joint Programming and Major European Initiatives, Directorate-General for Research, European Commission

Science advice and the management of risk in Government and business

10 November 2010

Sir John Beddington CMG FRS, Government Chief Scientific Adviser, Government Office for Science
Sir David Omand GCB, Visiting Professor, War Studies Department, King's College London
Professor Dougal Goodman FREng, Visiting Professor, The Risk Centre, Cranfield University
Professor David Spiegelhalter OBE FRS, Winton Professor of the Public Understanding of Risk, University of Cambridge

Digital Scotland - can Scotland grasp the opportunities created by the digital revolution?

28 October 2010

Professor Michael Fourman FRSE, Chair, Digital Scotland Working Group, The Royal Society of Edinburgh
John McClelland CBE FRSE, Chair, Scottish Funding Council
Rashik Parmar, Chief Technology Officer, North East Europe, IBM

Can we trust Government statistics?

20 October 2010

Professor Bernard Silverman FRS, Professor of Statistics, University of Oxford, and Chief Scientific Adviser, Home Office
Sir Michael Scholar KCB, Chair, UK Statistics Authority
Professor David Hand FBA, President, The Royal Statistical Society

Peak Water — can the developing world find the water needed for food production and a growing population?

14 July 2010

John D Liu, Film Director, China
Michael Norton MBE, Managing Director, Water and Power, Halcrow
Jennifer Schooling, Research Business Manager, Arup
Professor Chris Whitty FRCP, Chief Scientist, Department for International Development

The Scientific Century: securing our future prosperity — a joint meeting with The Royal Society to celebrate their 350th Anniversary

16 June 2010

The Lord Rees of Ludlow OM Kt FRS HonFREng, President, The Royal Society and Master, Trinity College, Cambridge
Sir Paul Nurse FRS FMedSci, President, The Rockefeller University and Member, Council for Science and Technology
Sir Richard Friend FRS FREng, Cavendish Professor, Cavendish Laboratory, University of Cambridge
Professor Adrian Smith FRS, Director General Science and Research, Department for Business, Innovation and Skills

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The Foundation for Science and Technology
10 Carlton House Terrace
London
SW1Y 5AH

Telephone: 020 7321 2220
Fax: 020 7321 2221
Email: fstjournal@foundation.org.uk

www.foundation.org.uk