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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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

Developing the next generation of vehicle engines

Projects that could put Formula One technology into buses and diggers, by developing the next generation of engines, are the first to receive money from a joint £1 billion government-industry programme.

The Advanced Propulsion Centre (APC) will see government and industry each invest £500 million in the sector over the next 10 years to research, develop and commercialise technologies for the vehicles of the future. The first £133 million of new investment was announced on 23 April.

According to the Government, the APC funding has the potential to secure up to 30,000 jobs currently linked to producing engines and create many more in the supply chain.

Consortia led by Ford, GKN, Cummins and JCB have all received funding for projects to improve fuel efficiency and reduce carbon emissions.

Lack of diversity 'a loss to the UK'

A lack of diversity across the scientific community represents a large loss of potential talent to the UK according to the chair of the Royal Society's Equality and Diversity Network (EDAN), Professor Edward Hinds FRS.

As a Royal Society report on the topic was launched, he commented: "With diversity comes a mix of ideas, skills and approaches. If the UK's scientific workforce is not diverse, we are bound to be missing out on some great talent. At a time when the UK is seeking to use its scientific capabilities to help improve lives and rebuild the economy, it is more important than ever that we ensure the best scientists can flourish."

Approximately 20 per cent of people in the UK workforce need scientific knowledge and training to do their current jobs.

The study found that science workers living in the highest income bracket households at age 16 were more than five times as likely to take a professional level occupation than those in the lowest bracket.

It also found that students from black and ethnic minority groups were less likely to progress to scientific jobs after graduating than white students, though the data relating to ethnicity is extremely mixed and complicated.

https://royalsociety.org/policy/projects/leading-way-diversity/uk-scientific-workforce-report

IPCC says 2°C limit still achievable

A new report by the Intergovernmental Panel on Climate Change (IPCC), released in mid-April, sets out how global emissions of greenhouse gases have risen to unprecedented levels despite a growing number of policies to reduce climate change. Emissions grew more quickly between 2000 and 2010 than in each of the three previous decades.

According to the Working Group III contribution to the IPCC's Fifth Assessment Report, it would be possible, using a wide array of technological measures and changes in behaviour, to limit the increase in global mean temperature to 2°C above pre-industrial levels. However, only major institutional and technological change will give a better than even chance that global warming will not exceed this threshold, says the study.

The report, entitled *Climate Change 2014: Mitigation of Climate Change*, is the third of three Working Group reports, which, along with a Synthesis Report due in October 2014, constitute the IPCC's Fifth Assessment Report on climate change.

Scenarios show that to have a likely chance of limiting the increase in global mean temperature to 2°C means lowering global greenhouse gas emissions by 40-70 per cent compared with 2010 by mid-century, and to near-zero by the end of this century. Ambitious mitigation may even require removing carbon dioxide from the atmosphere, argues the IPCC. Even less ambitious temperature goals would still require similar emissions reductions.

www.ipcc.ch

Catapult network to be reviewed

An independent review by technology entrepreneur Hermann Hauser has been launched to look at how the Government's Catapult network of elite technology and innovation centres can be fully exploited to benefit the economy in the long term.

The review was announced by Business Secretary Vince Cable during the opening of the Offshore Renewable Energy Catapult offices in Glasgow on 13 March.

Herman Hauser's initial review, entitled *The Current and Future Role of Technology and Innovation Centres in the UK*, was published in March 2010 and resulted in the establishment of the Catapult network.

Linking with emerging economies

The Government has launched a £375 million fund to promote economic development though science and innovation. The Newton Fund will improve the science and research capabilities of emerging powers and strengthen ties with Britain.

The fund will allow the UK to use its strengths in scientific research to promote economic development and welfare in emerging economies.

The fund will lay the foundation for ongoing collaboration between the partner countries and the UK, promoting the UK as an international partner of choice and seeking opportunities for commercial collaboration in the journey towards sustainable global growth.

www.gov.uk/government/publications/newton-fund-building-science-and-innovation-capacity-in-developing-countries

A new vessel for polar exploration

The UK is to get a new polar vessel. With funding of more than £200 million announced by the Government, the new ship should be ready for its first science mission in 2019. Owned by NERC (Natural Environment Research Council) and operated by the British Antarctic Survey (BAS) on behalf of the UK polar science community, the ship will deliver the next generation of UK marine science in the Antarctic and the Arctic.

The new flagship will build on the best features of both existing polar research ships; it will be larger, with greater endurance and ice-strengthened capability, enabling scientists to start research voyages earlier in the season.

Built with flexible laboratory configurations and the capability for containerised laboratories, the new ship will carry sophisticated environmental monitoring systems that will provide data from the deep ocean, the surface ocean and the atmosphere. It will be able to carry remotely-operated deep-sea vehicles, which can explore the harshest environments on the planet and explore the seabed in detail.

www.antarctica.ac.uk

Misconduct in scientific research

John Enderby

Professor Sir John Enderby CBE FRS is the Editor of *FST Journal*. He was Professor of Physics at Bristol University from 1976 to 1996. He was elected a Fellow of the Royal Society in 1985 for his pioneering studies into the structure and properties of liquids and amorphous materials. He served as a Vice-President of the Royal Society from 1999-2004. One of his responsibilities was the Society's publishing activities. Sir John was President of the Institute of Physics in 2004. He was the Chief Scientist at IOP Publishing.

Have you ever heard of the acronym 'FFP' or indeed 'CC BY'? What, if anything, has this to do with the dreaded Japanese knotweed? Allow me to explain.

FFP is the accepted shorthand for unethical behaviour in scientific research: it stands for 'Falsification, Fabrication and Plagiarism'. The Foundation's Chief Executive confirmed to me that, to his knowledge, the organisation has never held a meeting on scientific fraud. Yet, the issue is of increasing importance, especially given the emphasis on basing policy on evidence. Questions such as, how widespread is fraud, what motivates scientists to engage in FFP and does it actually matter, are largely ignored by many scientists.

When I was learning Educational Psychology as part of my teacher training at Westminster College, Sir Cyril Burt was regarded as the ultimate authority and we were all encouraged to read his books and papers. He was considered to be one of the most important psychologists in the UK.

Until his retirement in 1951 at the age of 68, he held a Chair of Psychology at University College, London. He received numerous honours including a Knighthood (the first psychologist to be so honoured) and in 1971, shortly before his death, he was awarded the Thorndike Prize by the American Psychological Society. His study of the intelligence of twins separated at birth concluded that intelligence was heritable and Burt was highly influential in Government policy-making regarding post-11 education. In short, for those learning educational psychology, Burt was a god-like figure.

Shock

Imagine, then, my shock when an article by Oliver Gillie appeared in *The Sunday Times* on 24 October 1976 with the headline 'Crucial Data Faked by Eminent Psychologist'. Citing work by Leo Kamin, Gillie concluded that the data on twins had been fabricated and that Burt's two research assistants, Jane Conway and Margaret Howard, never existed.

In 1979, his official biography, written by Hearnshaw, concluded that the charges made by Gillie were justified and, in 1980, the Council of the British Psychological Society endorsed these conclusions.

Not surprisingly, Burt's many admirers were distressed and several papers and books were written on what became known as the 'Burt Affair'. Many reacted strongly to the allegations made in *The Sunday Times*. In reviewing a book edited by N J Mackintosh and published in 1995, Professor Robert Audley wrote: "Whatever the prior opinions of the reader, this examination of the available evidence must surely be accepted as scrupulously fair and lucidly presented". Audley went on to conclude that "although some of the evidence he published in his later years is of doubtful scientific value, the contributions he made during a long professional life remain impressive, and I believe it is misleading to continue to hold him up as the icon of scientific fraud". The consensus now appears that some of Burt's papers were rather carelessly presented and perhaps it was a mistake to publish so much in his own journal.

A much clearer example of FFP is that of the highly-respected and much honoured Dutch social psychologist, Diederik Stapel. News broke in 2011 that Stapel had committed fraud on an industrial scale. In his autobiography (2012) Stapel admitted that he started committing fraud with minor data falsification and then moved on to outright fabrication. The extent to which fraud of this magnitude, coming from a leader in the field, has led to doubts about the subject as a whole was faced directly by Stroebe and Hewstone in *Times Higher Education* (THE) on 28 March 2013.

Physics

Physicists often felt that FFP was not a major concern in their discipline until the Schön affair. Here was a member of staff at the prestigious Bell Telephone Laboratory who published many papers in so-called 'top journals' (*Nature, Science, Applied Physics Letters*, etc) known for their high standard of peer review. At least 16 turned out to contain misleading and in some cases fabricated data.

For example, in 2001 Schön announced in *Nature* that he had produced a transistor on the molecular scale. Schön claimed to have used a thin layer of organic dye molecules to assemble an electric circuit that, when acted on by an electric current, behaved as a transistor. The implications of his work were significant. It would have been the beginning of a move away from silicon-based electronics and towards organic electronics. It would have allowed chips to continue shrinking past the point at which silicon breaks down, and therefore continue Moore's Law for much longer than predicted.

As a result of doubts about this work, Bell set up a committee chaired by the highly-respected physicist Malcolm Beasley. The 127-page report found substantial evidence for fraud and concluded that all the misdeeds had been performed by Schön alone. His co-authors were completely exonerated of scientific misconduct, but it was unclear whether all of them had exercised sufficient professional responsibility in trusting the integrity of his data. Schön was dismissed from his post and suffered other sanctions from his home university in Germany.

Widespread fraud

A charge of widespread scientific fraud, involving 26 articles published in 11 journals, was levelled by the University of Connecticut against Dipak K Das, one of its researchers, whose work reported the health benefits of red wine. Many of the articles reported positive effects from resveratrol, an ingredient of red wine thought to promote longevity in laboratory animals. The charges against Professor Das remain to be fully substantiated and indeed many of his colleagues strongly disapprove of the University's position and have exonerated him from all charges. A defamation case was brought by Professor Das against the University but sadly he died on 19 September 2013. Resveratrol is found in the skin of red grapes and in other fruits, as well as in the roots of Japanese knotweed. In fact, red wine contains very little resveratrol – of the order of 0.1-14.3 mg/l.

How widespread is scientific fraud? There have been relatively few detailed studies but most conclude that outright fraud is still comparatively rare. More worryingly, however, is that there is evidence that FFP is increasing and is perhaps driven by the highly-competitive nature of modern science. In 2011, *Nature* reported that there had been a ten-fold increase in the number of retractions over the previous decade.

An analysis, published in the *Proceedings of the National Academy of Sciences*, concluded that of the 2,047 retracted papers considered, 75 per cent involved scientific misconduct of one form or another. One of the authors, Dr Arturo Casadevall, stated that a major driver for scientific misconduct is the culture in which a paper published in a major journal can be "the difference between heading a lab and facing unemployment".

What can be done?

What can be done and by whom? In reality, everyone in the scientific enterprise must play a role in rooting out misconduct and thereby preventing public disillusionment with science. This must apply especially in subjects which attract immediate media attention such as climate change, energy and food security, as well as health. In particular:

- authors have a responsibility to keep rigorous records of data and to make them fully available as required. Schön, for example, had virtually no record of his experiments, stating that the raw data had been 'lost';
- a co-author, especially if a 'big name', must take full responsibility for that part of the paper attributed to him or her. Many journals insist that in the case of multiple authors, a clear statement of individual contributions must be made. The danger is that the appearance of a highly-respected name on a paper might unconsciously influence the decision of a referee or editor;
- heads of institutions have a responsibility to ensure that good practice is part of accepted culture. In an important THE article in April 2013, Watson and Hayter argued that universities must play a major role in monitoring research outputs at the point of submission, as well as maintaining adequate databanks for external scrutiny;
- publishers bear special responsibilities. First, they must ensure that referees are truly impartial and unlikely to be influenced by the reputational capital of the authors. Publishers should also use modern software to detect plagiarism. Papers found to be fraudulent must be retracted at the earliest opportunity and sanctions applied to the offenders. Papers emanating from the Editor or his or her institution need truly independent assessment, something which did not happen in the Burt case.

Creative Commons

Research Councils UK (RCUK) has announced that the Creative Commons Attribution licence (CC BY) will be applied to articles it funds. The CC BY licence is the most liberal of the CC suite and many colleagues are worried about the implications.

CC BY allows anyone to copy, distribute and transmit the information contained in the publication without permission of the copyright holder. Moreover, it permits re-mixing with other material and allows both commercial and non-commercial use. While CC BY does require full attribution, some commentators feel the attribution portion of a CC license may be difficult to enforce (see for example Crotty's article in *http://scholarlykitchen.sspnet.org*) leading to fears that this form of copyright protection might be a charter for plagiarists.

In response to worries on this score, the CC organisation, in its advice to the Department for Business, Innovation and Skills (BIS) stated: "Plagiarism is a completely orthogonal issue to copyright infringement, and there is simply no evidence we know of that would support a claim that CC BY would promote or encourage plagiarism". Nevertheless, there seems to be a problem with self-plagiarism and this is an issue which individual publishers need to manage.

Has this Editorial highlighted issues which might form the basis for one of our evening dinner/discussions? Answers please on a postcard (or is it by email?) to the Foundation – *office@foundation.org.uk.* □

How can decision makers be helped to understand the inherent uncertainty in risk model selection and outputs? Can policy be evidence-based when model outputs have wide bands of uncertainty? These questions were debated at a meeting of the Foundation for Science and Technology held on 5 February 2014.

Communicating risk and uncertainty in science

Mark Walport

There are several aspects of risk that have to be borne in mind by scientists who advise Government. The first concerns the terminology involved, specifically the distinction between risk and hazard, two terms which are often confused. Second, scientists must recognise that policy makers and, indeed, the public, look at issues through different 'lenses', including different values. Then, too, there is undoubtedly the challenge of clear communication.

The assessment of risk is at the heart of the work of the Government Office for Science. Among the urgent issues currently being studied by both the US and UK governments are the risks associated with space weather, specifically the possibility of another solar storm like the 1859 Carrington Event. What would be the consequences for telecommunications, electrical grids and satellites?

Flooding is extremely topical with questions being raised about the consequences of building on flood plains and the appropriate level of spending to make such housing safe to live in.

Those are natural hazards but there are also human threats – terrorism, emissions of carbon dioxide and other pollutants into the environment, for example.

The Government produces a freely-available National Risk Register[1]. A simple and effective way to represent risk is to classify each according to both impact and likelihood (see Figure 1). Risk registers can be utilised to help prevent undesirable events, as well as to mitigate, manage and clear up when they do occur. But can they also be used to decide the relative investment that one allocates to different threats? Can they provide a basis for evaluating investment options? Decisions have to be made about how public money should be spent, after all.

Sir Mark Walport FRS FMedSci is the Government Chief Scientific Adviser at the Government Office for Science. Previously, Sir Mark was Director of the Wellcome Trust. Before joining the Trust, he was Professor of Medicine and Head of the Division of Medicine at Imperial College London. He has been a member of the Prime Minister's Council for Science and Technology since 2004.

Risk and hazard

Risk is commonly defined as the product of hazard exposure and vulnerability. Yet there is a great deal of confusion about the terms 'risk' and 'hazard'. The issue of pesticides illustrates this clearly.

The question involves pesticides, pests and pollinating insects. The EU has recently imposed a moratorium on the use of neo-nicotinoid pesticides in agriculture, but the UK opposed this decision. The issue is not whether neo-nicotinoid pesticides are hazardous to insects: they are designed to be extremely hazardous, hence the term 'insecticides'! They should, though, kill the undesirable insects while having limited impact on the insects that society wants to encourage.

The key question, then, is: "Under field conditions, is the exposure of other pollinating insects to these substances unacceptable?" If exposure is at a safe level, then the insecticide will achieve its aim, killing the unwanted insect, not the useful one. The problem, to be frank, is that the evidence available is not robust enough to answer this question.

In laboratory conditions it is possible to show how neo-nicotinoidal insecticides can have deleterious effects on bumblebees, honey bees and other insects. What is lacking is clear evidence that, when applied according to the manufacturers' guidance, they still have toxic effects in the field.

This distinction between hazard (and many things are hazardous) and risk is a continuing challenge for regulators. There is a tendency to regulate by hazard rather than by risk.

With new technologies, there is the further issue of communication about the risks involved. There are risks associated with almost everything humans do: they have to be managed and not ducked. Unfortunately, there is too often a tendency to duck.

In the case of Genetically Modified Organisms, the mistake was to talk about them in a generic sense, yet there is nothing generic about a GMO. By focussing on the specific purpose, the individual organism and the nature of

DISCUSSION

Scientific advice

How does uncertainty impact on scientific evidence and the advice tendered to decision-makers through trusted advisers? Decision-makers may need to act very quickly when the scientific evidence is not complete and there are still areas of uncertainty. Uncertainty is not a ground for rejecting scientific advice though, since uncertainty applies to other areas as well, such as public opinion, the attitude of the courts, and foreign reaction. It is important to find ways of explaining to decision-makers the range of uncertainty - whether it is fundamental, or does it apply only to specific, less-important aspects of the question?

Figure 1. Likelihood of current risks plotted against overall relative impact on a 1-5 scale. Source: National Risk Register of Civil Emergencies 2013.

the genetic modification, there can be a sensible discussions about hazard and risk. It is not helpful to treat a whole technology as though it poses a single risk.

The Precautionary Principle

The Precautionary Principle is often brought into these discussions. It is assumed to mean that if there is any possibility of anything harmful, then that choice should be avoided. However, this is only one interpretation.

The UK Government interprets the EU communication on the Precautionary Principle as requiring the fullest possible scientific evaluation of the hazards, exposure and vulnerabilities associated with a particular choice. A decision to act or not is preceded by an evaluation not only of the hazard but also the consequences of not proceeding along this path – in other words, the consequences of inaction. The Precautionary Principle should be transparent; it must take into account the general principles of risk management (in other words being proportionate), it will involve thorough risk/benefit and cost/benefit analyses and include constant review as new evidence emerges.

Unfortunately, regulators are frequently subjected to asymmetric incentives. There will be trouble if something is allowed to go forward which causes harm. However, there is no consequence for stopping something happening that would actually have brought benefit. This is a profound problem because it means that the incentive system is loaded entirely in one direction. Society should recognise that harm can frequently flow from omission as much as commission.

The confusion between risk and hazard can lead to different parties in an argument talking at cross-purposes without realising it. The fracking debate is a very good example. On the one hand, there are legitimate scientific and engineering questions about hydraulic fracturing: will there be any damage to aquifer zones by leakage of contaminated fluids; will there be significant side effects; will fugitive methane be released? These are key questions. Now, the Royal Academy of Engineering has concluded that all of these concerns can be managed where best practice is applied.

Go and talk to the protestors in Sussex, though, and there is actually a different conversation taking place. Some of these people are totally opposed to the oil and gas industry, some simply do not like capitalism, while others are motivated by a 'not in my back yard' attitude.

Different lenses

To communicate effectively, it is necessary to look through the 'different lenses' that various parties have on these issues. Studies show that about three-quarters of the population are fairly or very concerned about climate change; they believe the UK should reduce its use of fossil fuels. A similar proportion are concerned that electricity and gas will become unaffordable and a very similar proportion again (70-80 per cent) are concerned about energy security. These are the three policy lenses which are important, of course, when talking about energy.

There is then work to be done in exploring people's values around, on the one hand, the finite nature of resources, linked to people's feelings about waste, efficiency, environmental protection, social justice and fairness. On the other there are the issues of availability and affordability, reliability, safety, as well as freedom of choice.

It is vital to understand the nature and interplay of these issues seen through different lenses if there is to be a sensible and constructive debate. □

1. **https://www.gov.uk/government/publications/national-risk-register-for-civil-emergencies-2013-edition**

The commercial management of risk

Tom Bolt

Every successful economy has found a way to manage risk (which is another word for 'uncertainty'). Formal risk transfer, where a business removes uncertainty from its balance sheet by taking out an insurance contract, has been used for centuries. The basic premise has always been that insurance exists to absorb other people's uncertainties so they can plan and, critically, grow their businesses. So in some ways, Lloyd's is a public repository of uncertainty.

For the last 325 years, Lloyd's underwriters have specialised in 'decision-

Tom Bolt is Performance Director at Lloyd's of London – the insurance market. Previously, he was Managing Director of Marlborough Managing Agency. He has extensive experience in international insurance and reinsurance across the UK, USA and Europe and has held senior roles in Berkshire Hathaway's reinsurance divisions and as President of some of its insurance subsidiaries. He also assisted in the formation of Bankers Trust Insurance Derivatives business, as well as a related group of insurance and reinsurance companies.

making under uncertainty'. Until the Derivatives boom of the late 80s and early 90s, bank balance sheets were reasonably fixed and determinable. Deposits were fixed and loans were absolute amounts. With the advent of Options, Futures and Derivatives, banking institutions introduced uncertainty to their balance sheets in unprecedented ways.

While much of the 2008 and 2009 financial crisis was down to the age-old problem of over-leveraging, a part was due to Bank Boards not fully appreciating how probability-driven their financial statements really were.

Jump risk

Insurers are largely firms which buy and hold what might be termed 'jump risk'. Derivatives traders operate on the concept that there will be a continuous market for their instruments. In other words, every morning they can get up and they can trade on the Exchange. Jump risk comes from discontinuity. For example, if the Japanese Stock Market were to close following an earthquake and not open for two weeks there would be a big gap between the level where it last closed and where it opened up again – there would be a 'jump'. Jump risk is difficult for derivatives traders – which is why they pay large sums to protect against it. At Lloyd's there is an entire building of what might be called 'jump risk underwriters'.

The insurance industry has tools and techniques for communicating levels of risk. It also uses modelling extensively and I believe we are better off with models than without them. However, they are approximations and they have some weaknesses.

Insurable risk

Lloyd's deals with several types of risk: event risk is essentially about 'acts of God' such as earthquakes, hurricanes, tsunamis, floods, brushfires caused by lightning, hailstorms etc.

Actuarial risks are those events or acts of God which have sufficient data or observations for the law of large numbers to be used as a way of determining frequency and sometimes quantum.

Behavioural events are those acts of man where the law of large numbers can be applied to begin to assess the risk (motor, etc).

Lloyd's typically covers the risk that people find hard to insure in their local markets; for example, property exposures on the East Coast of the USA which is at significant risk of hurricane damage, or property in California that is at risk from earthquakes. A great deal of our business is commercial risk – this may include construction projects, offshore oil platforms, major buildings owned by property companies, aircraft, ships, professional negligence – in short, just about every aspect of the economy. That is why, over the years, Lloyd's has paid out on Piper Alpha, the World Trade Centre, the Costa Concordia, Deep Water Horizon, Hurricane Katrina, Thai flooding – in fact most disasters.

Pricing is an art and, increasingly, a science. Yet in all calculations, there are estimates involved for different factors. The expected level of claims is assessed using statistical models (ranging in complexity and often based on past claims experience), or physical models of the claims process, often merged with engineering and scientific models. Expenses have to be calculated and, within this, inflation is one of the great imponderables for the coming years. There will be repair costs, regulatory compliance, medical costs, legal fees, general inflation – all of which involve some uncertainty.

With actuarial risks, such as car accidents, there are plenty of traffic collisions which enable the industry to fine-tune its estimates. For earthquakes on the other hand, it is very hard to get that estimate right. This makes estimation of frequency troublesome – scientists have proved invaluable here by augmenting the small amount of actual claims experience we have with proxy data. Even so, investors in these sorts of risk demand a higher return on capital due to the additional uncertainty in earthquake business than motor.

The best summary of the sources of uncertainty in using models comes from Peter Taylor of Oxford University. As Table 1 shows, there are items of model uncertainty, data uncertainty and un-modelled uncertainty. The Tohoku earthquake, which caused the 2011 Tsunami in Japan, caused some to criticise the standard modelling, for example. But a magnitude 9 earthquake was not thought to be possible in that region and so none were included in the models.

Scrutinising modelling

Lloyd's scrutinises the models used by the members of its market to ensure that they understand the strengths and weaknesses of those models – the nuances, the appropriateness of fit for the model against the portfolio. We also seek to ensure that the uncertainty factors around the use of the models are communicated very effectively to the board of the underwriters, especially when the members are being given a number derived from the model – a 'willing to lose' number, in a sense, for big events like the California quake or Japanese earthquake. People need a frame of reference when they are told they might, say, lose over $4 billion with a particular probability. They also need to understand the uncertainty factors underpinning that statement.

DISCUSSION

Trust and advice

A trusted expert adviser will be trained to consider all the risks involved in planned policy changes. They will use a risk register and identify who owns each risk, who will be affected and what the probability and consequences of an event arising from the policy are likely to be. At the centre of the relationship between adviser and decision-maker is trust. However, 'trust' does not mean that the adviser shares closely the ambitions of the decision-maker, and becomes reluctant to press alternative views, or even to become subject to 'group think'. This could, perhaps, be a danger in the public service where Ministers feel bound by a manifesto or other commitments, and find advice which stands in their way unhelpful.

Model uncertainty	Data uncertainty	Unmodelled uncertainty
Model inadequacy	Wrong location	Secondary perils
Model risk	Understated values	Contingent business interruption
Parameter risk	Building risk profile	Policy wordings
Calculation error	Schedule out of date	Loss adjustment expenses

Table 1. Uncertainties in modelling. Source: Peter Taylor.

It would be a major advantage if the language could be simplified and more easily understood. It could then be used more widely across business and industry, providing people with a better view of what is happening.

It is not the aim of Lloyd's to run a failure-free regime – we are, after all, taking risk from everyone else in the economy to soften the risk of their failure. At some point this will happen and what I want to make sure is that if underwriters 'blow-up' due to this uncertainty, the exposure is limited to a defined amount, i.e. the capital that has been put up!

Yet people do need to be sensible about what they are doing and so we monitor systemic risk. One of those systemic risks is the use of models. One of our model vendors has 38 out of our 54 agencies in its customer base. Now, if there is a flaw in that model, it has effects throughout the system. That is one of the reasons we encourage the use of other models, as a way of suggesting people should evaluate uncertainty in a variety of ways.

While models are very useful (they make a very useful skeleton upon which to hang the rest of the underwriting process) there is also the aspect of sound judgement, which is what underwriters get paid for.

Modelling losses

Regulators essentially want to know what our estimated 1-in-200 year losses amount to. That is difficult though, given that the modern insurance industry is only 25 to 30 years old and earlier loss data is hard to model with any degree of confidence. Different types of uncertainty can swamp our models. It is important then to be able to make clear the uncertainty surrounding any 1-in-200 assessments in order to avoid misinterpretations. Over-optimism as well as too much pessimism can be equally unhelpful. The challenge for the actuaries is to communicate uncertainty in a way that is effective, but not career-limiting!

In my department we try to maximise market skill and understanding of the data. We look mainly at risks that are systemic and focus on areas that present the biggest dangers to the market as a whole: chief among these are the accumulation of property values in high risk zones around the globe.

To sum up, Lloyd's works with people that could be termed 'merchants of uncertainty'. It tries to ensure they are not taking on overwhelming risk: after all, our promise is to honour every legitimate promise to pay and this has been the case for Lloyd's for 325 years. ☐

Whose risk is it anyway?

Judith Hackitt

The Health & Safety Executive (HSE) is a statutory consultee for planning applications concerning major hazard sites, pipelines and applications for hazardous substances consent across Great Britain. Our advice aims to mitigate the potential effects of a major accident on the population around a major hazard site.

The chemicals industry provides many benefits to us all, but it also presents risks. Where hazardous substances are present in large quantities, the consequences of major accidents in terms of loss of life, injury, damage to property and disruption to essential services can be very significant. This has been evidenced in major accidents in the UK at Flixborough (1974) and Buncefield (2005), across Europe at Seveso (1976), Enschede (2000) and Toulouse (2001), and elsewhere in places such as Bhopal (1984) and Mexico City (1984).

Ideally, industries using large quantities of hazardous substances would all be located far away from highly populated areas. In reality, factories, housing, schools and shops have developed close to each other; indeed, in many cases the hazardous industries themselves provide the economic heart of the local community.

In the UK, given our population density the pressures on suitable land for the development of housing, retail, public use, etc, present significant challenges. The desire to retain green space leads to a preference for brownfield development, but this often leads to demands for land adjacent to existing hazardous installations to be used for housing, schools, hotels, shopping centres and other amenities. This can lead to large numbers of additional people being brought into the zone of risk.

Options are limited even when planning the location of new hazardous activities. Few locations exist where new hazardous installations can be sited without creating some risk to an existing community. Yet remote locations may be unacceptable for very good environmental or economic reasons.

So, the reality is that safety is one among a number of elements to be considered by local planning authorities. A balance must be struck between the needs of industry and the community, both now and in the future.

As a statutory consultee, HSE can advise against developments, but the decision to act on that advice rests with the local authority. There are numerous cases where a planning authority grants planning permission against HSE's advice. In most of these, HSE recognises that the authority has made a balanced judgement and so takes no action. On rare occasions (there have been just six in the last 40 years), HSE has exercised its right to request the decision be 'called in' and made by the Secretary of State for Communities and Local Government.

Risk communication

The challenges HSE faces are twofold, and they are related. The first is to present its advice on the nature of the

risk in a way that does not present us as standing in the way of community benefit; of the hotel, shopping centre, school or whatever is being planned for development. The second is how to explain ourselves clearly to those with a different perspective, knowing that we are dealing with multiple uncertainties.

Some residents will have lived near a major hazard facility for years and know that there has never been a major incident there. Yet a proposal to build additional housing, a school or a hotel, will trigger a consideration by HSE of the total number of people who could be affected by an incident at the new development. This may result in the potential number of casualties being deemed unacceptable. Now, the long term resident who has lived there for 30 years will find it very hard to understand that the same hazard now presents an unacceptable risk when there has never been a problem before.

Some residents may depend for their livelihood on the major hazard site and get an immediate benefit from its existence. Positioning a new school next to that site may seem preferable to parents when compared with an alternative location which may, for example, require pupils to cross a busy main road every day. How does one weigh up the arguments associated with complex, low-frequency, high-consequence events as against familiar hazards and consequences which people encounter every day?

Whose risk?

The HSE provides advice to local planning authorities which will allow them to make informed decisions that reflect an understanding the risks. But when a local planning authority goes against our advice – who owns the risk? What happens if a major incident occurs? Who will the community and the media look to, to explain why particular decisions were taken?

If we advised against the development but it went ahead, do we have to approach the major hazard site to take action to further reduce their level of inherent risk in light of the development? What about people who move into the area after the development? Are they informed about the risk? By whom? How?

In January 2008, a planning application was submitted to redevelop part of the Oval Cricket Ground. The proposal was to replace stands and some minor buildings with a new plaza, a six-storey stand incorporating around 2,000 additional seats and a hotel. The development would be right next to the Kennington gasholder: a top-tier COMAH (control of major accident hazards) site.

Judith Hackitt CBE FREng is Chair of the Health and Safety Executive. She worked in the chemicals manufacturing industry for 23 years before joining the Chemical Industries Association (CIA) in 1998. She became Director General of CIA and then worked in Brussels for the European Chemical Industry Association (CEFIC). Judith Hackitt is President of the Institution of Chemical Engineers and a Fellow of the Royal Academy of Engineering. She is also a senior non-executive director and trustee of the Energy Saving Trust and a non-executive director of the High Value Manufacturing Catapult.

HSE advised against the development because of its proximity to the gasholder and the significant increase in the number of people close to the gasholder in the new development and therefore at significant risk in the event of an explosion.

The application was nonetheless approved. HSE then requested that the application be 'called in'. A planning inquiry followed and the decision was made to grant planning permission for the development. HSE's safety advice was acknowledged by the planning inspector but on the balance of risks versus benefits the application was cleared.

A new approach

For us, the process had been expensive and inefficient. The lessons included the need for frequent communication, more face-to-face meetings, involving a wider range of stakeholders and, perhaps most importantly, being involved at an earlier stage. There are also some cautionary notes about the use of tools designed to help decision-making but which can act as a barrier to early communication.

More recently, a similar case, near a gasholder close to the RAM brewery in Wandsworth, has turned out rather differently. Here extensive engagement between HSE and stakeholders led to a mixed-use residential and commercial development going ahead but with significant risk reduction from the original plans. Earlier engagement with a broader group of stakeholders enabled us to influence the design so that risks could be minimised. This was achieved through measures such as: re-orientating the development within the site to move high occupancy further away from the hazard; adjusting heights of structures, location of windows and points of access.

So our current thinking on risk communication and uncertainty in the context of land use planning is that we have to reposition ourselves. This repositioning has three elements: when do we engage; who within HSE does it; and how do we engage in terms of the substance of our advice?

Our engagement must be earlier in the process and focussed on working with planners and developers, so that new facilities are designed in ways that minimise risk.

We need to develop a role as 'risk educators'. By moving this function from our regulatory staff within the Hazardous Industries Directorate to our Health and Safety Laboratory (HSL), we act as advisers to the planning process rather than as regulators of the health and safety at work process.

We are constantly seeking to improve communications and understanding so that we can collectively find solutions rather than polarising the debate into who is right/wrong and who owns the risk. A jointly-developed solution that reduces death and injury in the event of a low-risk, high-impact event surely benefits everyone involved in the development.

Stakeholder engagement

How we engage with other stakeholders must change too. Many of us love QRA - Quantitative Risk Analysis. In a world of uncertainty we seek to attach a level of numerical certainty to the chances of an event happening, but how helpful is it in stakeholder engagement?

QRA has its uses, but not in the area of risk communication. A risk probability of $1x10^{-6}$ may mean something to risk professionals, but it can give a false sense of security to some that the event will never happen and can therefore be ignored.

The impression of certainty over something which is inherently uncertain also leads to mistrust of experts. Residents of the Somerset Levels are clearly very confused and upset that floods which experts said should only happen once in 100 years have now occurred two years in succession.

Explaining risks, particularly those which people do not see everyday – and could therefore instinctively understand – is one of our big challenges. Communication has to be combined with education. ☐

Can university-business collaboration help maximise short-term economic growth and reduce unemployment in economies like Wales? The question was debated at a joint meeting between the Foundation for Science and Technology and The Learned Society of Wales on 3 July 2013.

The contribution of Higher Education to the regional economy

Colin Riordan

A recent report by Higher Education Wales (HEW) showed that HE creates tens of thousands of jobs[1]. It generates about 3 per cent of Welsh GDP and it creates over £400 million in export earnings: this is mainly through overseas revenue from international students coming to study in Wales, but also from research collaborations and other international activity. Welsh HE generated 38,802 jobs across the country and more than 43,000 UK-wide in 2011-12; so that is really a significant impact.

Every million pounds of university revenue generates a further secondary output of just over £1 million in the Welsh economy. This knock-on effect is to be found in supply chains, in purchasing links, in staff spending and of course in student spending as well. As universities grow so the economy grows.

Cardiff University, for example, is the third largest employer in the area, with over 6,300 staff. Some 28,000 students bring in an estimated £200 million annually to the local economy. Around 27 per cent of the international student population in Wales study at Cardiff, making a contribution of around £45 million to the local economy.

Investment

Further short-term economic benefit and more jobs can be achieved through capital investment. Cardiff University is investing around £400 million over the next five years or so, not just in student and research facilities but also in innovation centres and research translation hubs. That investment alone will create jobs (directly and indirectly) now and in the future.

The university's research base supports more than 1,800 research grants and contracts valued at around £500 million. Some 80 per cent of that is funded from outside Wales which represents a major inward investment.

University research itself has a powerful economic impact and engages across a wide range of sectors. World-leading research in Cardiff and other Welsh universities is critical to economic success. We work with industries and businesses across Wales, including multinationals like Ford and Tata Steel. Importantly, though, we are also engaged with more local companies – Cassidian and the Media Standards Trust for example.

Universities offer consultancy services to business and industry, giving them access to expertise in specialised areas. They offer professional training as well as postgraduate programmes which provide highly-skilled graduates to the workforce. In many ways that is the critical element: businesses want access to research expertise but above all they want highly-qualified people. The universities create graduates who are capable of setting up their own businesses as well as creating jobs and wealth.

Our seed venture fund, called the Cardiff Partnership Fund, has invested more than £4 million in 48 projects (including almost £2 million invested in 14 spin-out companies) since it was started just over a decade ago. These projects have since leveraged £60 million in follow-on investment from a wide range of sources.

The university's Commercialisation Initiative supports spin-out company activities in collaboration with Fusion IP plc. The initiative invests in new and existing spin-out companies. Fusion now has more than 20 companies in its portfolio, of which 10 are based in Wales. About £25 million has been invested in Cardiff University spin-outs.

Knowledge Transfer Partnerships (KTP) are also critical. Cardiff University currently has 21 active KTPs where university academics and students work together with companies, supported by a Government grant, to create or improve a business or industrial process, management methodology or indeed a technology.

Innovation

In the longer term, innovation will be the key to economic growth and

Professor Colin Riordan FLSW is President and Vice-Chancellor, Cardiff University. Previously he was Vice-Chancellor of the University of Essex. In 2009, he chaired the Higher Education Funding Council for England's enquiry into teaching quality. Professor Riordan is Vice-President of Universities UK and sits on the boards of UCAS, the Edge Foundation, the Leadership Foundation for Higher Education and the Equality Challenge Unit, which supports equality and diversity for staff and students in Higher Education across all four nations of the UK.

DISCUSSION

Skills have to be learned throughout life

It is not sufficient to ensure that graduates are well-prepared for their first job. In the modern world, with rapid technological change and the possibility of a number of major career changes, graduates need to have the capacity to relearn. For this reason, curriculum design has to meet the needs of several stakeholders, including both students and employers. Innovations such as the Raspberry Pi (production of which has now been brought back from China into Wales) can greatly enhance the ability of students in information and communications technology (ICT) by introducing them to programming.

prosperity, and we all need to create the environment where innovation can flourish. To achieve this, it is vital to build and maintain a culture of innovation throughout the university, not just involving staff but students as far as possible as well. It is important to develop an innovation system here in Cardiff but it has to occur in collaboration with other universities, with Government and, most importantly, with industry. Wales also needs translational research facilities which bring together academics and private enterprises.

Social scientists will play an integral part in the process, operating in areas such as science policy research, supporting the R&D process by taking part in early-stage technological development to help avoid expensive and time-consuming pitfalls, as well as advising on the public acceptance of technology. It is all very well inventing shale gas technology and GM foods, but if that creates a public outcry we need to know before we encounter serious setbacks and we need to have a strategy for addressing the reaction.

In Wales, creative and heritage industries are critical to future economic growth so we intend to create, for instance, a creative industries hub which will allow us to foster work in that area as well. The Arts and Humanities have an important part to play in the future of the Welsh economy.

Student involvement is essential to success. It needs to be built in from the start, through enterprise education for both graduates and undergraduates. Undergraduates must be exposed to the processes of innovation during their time at university, from the initial planning right through to eventual success.

There need to be places where people can meet to discuss ideas they would not otherwise come across; from different sectors, from academia, from business, from students.

At the most basic level, the will to succeed is what will make the difference. We in Wales have to decide, collectively, that we will be outward-looking and re-invigorate our economy through education, innovation, research and development as well as business/university interaction, driven by a shared vision of the future. □

1. **www.hew.ac.uk/wp/media/2013-June-The-Economic-Impact-of-Higher-Education-in-Wales1.pdf**

The key to economic success

Leszek Borysiewicz

Across the European Union, one quarter of people between 18 and 25 years of age are unemployed. So Wales is not unique. A McKinsey report[1], launched in Davos at the World Economic Forum in January 2013, noted that, globally, 75 million people under the age of 25 are unemployed.

Half of those leaving post-secondary education do not believe that education has played any part in their employment prospects. Some 40 per cent of employers say young people are lacking in relevant skills. Yet 72 per cent of providers think they are delivering on skills (it transpires that 50 per cent of the employers who complained have never spoken to the post-secondary education sector). Now those are global statistics but the UK numbers are very similar.

Where economic success has been identified, employers and post-secondary education work together. So local solutions are the only way to successfully tackle the problem.

However, if answers can be found at that local level, then the second tier challenge is to scale up. Anyone in industry will say that scale-up is the vital ingredient for doing things really effectively. Scale-up is going to require the use of innovative technologies and it will also need the application of these through enhanced skills. What are the most effective (and cost-effective) ways of inculcating these skills in our young people?

Apprenticeships are really sought-after, but there are simply not enough to go round. Perhaps technology itself can be used to increase the effectiveness of training?

In addition to the short term issues, there are longer term questions about the economy and the role of universities. The enterprises we spin-out from universities are going to be small. They will not have the capacity to replace Tata Steel, for example, should it withdraw from parts of the industrial network.

Promoting entrepreneurship

In terms of attitudes, universities must foster a culture in which it is equally good to be an entrepreneur as it is to be an academic. At Cambridge, despite its reputation for ivory towers and blue-sky thinking, the most popular student society is the Entrepreneurship Society. It is interesting to note that as many members come from the arts and the creative sector as from engineering and technology. Universities must foster that interest.

The Raspberry Pi was created in Cambridge in 2008 because applicants to Computing Science in Cambridge did not know how to programme. Up until 1995, virtually every single applicant to Computing Science knew how to write a programme and that was because they grew up with Spectrums and BBC Micros which did not have much software. People could have fun with them by writing the programmes for themselves – even I was able to connect my computer to a gamma counter in order to get counts more easily than sitting there all night.

Production of the Raspberry Pi is now based at Sony in Bridgend. This shows that Wales has the skills to produce this in a competitive way compared to other parts of the world. More than 1.5 million Raspberry Pi units have been produced in Wales so far. Students are learning how to programme using this and they will find ways to improve it for the next

DISCUSSION

Business success

Wales has a relatively poor record, in relation for example to Scotland, of securing funding from the Technology Strategy Board and the Research Councils. It is not just the number of and quality of applications that counts but also the vigour with which these are submitted and followed up. For the Welsh economy to grow and prosper, there has to be not only a continual flow of innovation-led new businesses, but also a readiness to allow natural selection to take place. The weakest ventures must fail and the strong ones grow in size and scope. Wales needs more big winners!

generation. That is innovation, that is entrepreneurship and that is how growth happens. There are success stories in Wales and we need to celebrate them.

Clusters

A feature of universities, which helps to drive entrepreneurship, is that sooner or later they develop a 'clustering effect'. Companies look for places where they can find a spirit of entrepreneurship and a focus on innovation. In universities, Britain has some of the best innovation centres anywhere in the world, so why is it that people talk about importing these skills from outside?

However, one has to be careful what metrics one uses to judge their effectiveness. What can kill such centres is the kind of assessment based on third-party licensing income. If you look at Cambridge, the figure is zero – we give away much of our intellectual property because we want to create a local culture of entrepreneurship. From this approach has come the Cambridge Cluster. It originated in 1960 when two people decided to put innovation to work locally.

Even in 1995, Cambridge had no billion-pound companies: today it has 12. The Cambridge Phenomenon now encompasses 1,500 companies and employs 54,000 jobs, all created from scratch.

Success brings its own challenges. We are short of the technical staff we need to service these companies. Any incoming company asks for three things of the local economy: good transport links – i.e. an international airport, motorways, easy transit times to London; local education of the highest quality – people will demand that the schools deliver the highest quality schooling for their families; and a high standard of housing.

Professor Sir Leszek Borysiewicz FRS FRCP FMedSci FLSW is Vice Chancellor of the University of Cambridge. He began his career at the Welsh National School of Medicine, the Royal Postgraduate Medical School in London and Addenbrooke's Hospital in Cambridge. In 1991 he returned to his home city of Cardiff when he was appointed head of the Department of Medicine at the University of Wales. He went on to be Deputy Rector at Imperial College and the Chief Executive of the Medical Research Council.

What attracts businesses? One thing – the Innovation Centre and the people that drive it. Microsoft moved to Cambridge because Roger Needham was there, someone they wanted to work with. That was enough for them to create their third institute, the others being in Seattle and Beijing.

Unpredictable

Now innovation is inherently unpredictable. In 2000, Amazon was a bookseller. Today, less than a decade and a half later, it is the biggest logistics and distribution industry in the world and has completely revolutionised the way we think. In 2000, who could have predicted an innovation like *Humira*, the biggest-grossing drug of all time, with £9.3 billion sales in 2012. This treatment for breast cancer is changing the very nature of that disease.

What are the possibilities for South Wales? Well, the Welsh Assembly is working with the Higher Education sector to look at ways to stimulate employment – that will be a big asset. Then there is Europe and particularly the structural funds which places like Cambridge, for example, cannot access. But innovation should not just be focussed on South Wales. There are opportunities for Cardiff to work with bodies in Bristol and the South West. The rest of Wales could be encouraged to engage with this wider perspective too.

It is, though, essential not to fall into the trap of expecting a 95 per cent success rate. Successes of a little more than 50 per cent mean that sufficient risks are being taken. Some enterprises are going to fail and this is a very difficult message for politicians to give to taxpayers in these hard-pressed times. The innovation community has to support politicians when they start making difficult decisions and are criticised by the media for 'wasting money' on failed projects.

Short-term exploitation can help deal with the immediate issues facing the country like youth unemployment. To do this effectively, much greater working together between education providers and industry is vital. This will also lay the foundation for the longer term success of the economy.

Last but by no means least, make sure there is a stable research base within the universities because once this economic success story has been established, half the world is going to try to poach the talent! □

1. **http://mckinseyonsociety.com/downloads/reports/Education/Education-to-Employment_FINAL.pdf**

The vital importance of focussing on the customer

Terry Matthews

One very important ingredient in any economic success story is the connection between education – universities and young graduates – to local companies, that is universities with their partner companies. Until about 50 years ago in Wales, there were many centres of Further and Higher Education that focussed on the needs of the main local industries: coal mines, iron and steel production, non-ferrous metal processing, and supporting companies. When students graduated they were trained and guaranteed a job. Today, a large percentage of young people cannot get a job at all!

My approach over the last 20 years has been to help young graduates create their own companies instead – their own jobs in fact. My first company was started with $4,000 and grew to have a turnover of $1.5 billion. The lesson there is that it often does not take a huge amount of money to create a successful start-up. Yet it does take drive and passion and a strong team spirit. It also needs committed clients: any venture is far less speculative if there is a clear client need being addressed.

Recently I established a new vehicle to build closer relationships with universities. The Alacrity Foundation is located here in Wales as well as in North America. It was set up to connect graduate entrepreneurs

with known client requirements, i.e. areas where there is a potential for strong customer pull. That significantly reduces time to market for a product or solution because of the focus provided by the client. The business has a much greater likelihood of success as a result.

The Alacrity Foundation also provides start-up companies with access to mentors who provide them with credibility, and this helps build relationships with clients. Credibility is a vital ingredient in business. Start-ups need business from clients but have no track record to show what they have done or whether they will be around in a year's time.

I am a big believer in internships or, as we used to call them, 'sandwich courses'. Typically that was how the HND, HNC qualifications and so on were structured; it was a very good programme for educating young people about business. That approach seems to have been lost in our current education framework. I would like to see it make a comeback.

So, the Alacrity Foundation assists universities in placing students in targeted industries and partner companies. By virtue of the Wesley Clover network, it also gives these students opportunities to go to other countries as well, like North America, France or Germany. This exposes them to the experiences of global markets.

Our universities produce really good graduates. I know, we actively embrace them. In Wales, and elsewhere in the UK, we have very innovative young people. What is lacking is a more effective way to commercialise their insights, to take their ideas – and the innovative people themselves – and turn them into businesses and business people. How can this gap between idea and commercial reality be crossed, since it seems to be inherent in the society? The problem is certainly not a matter of work ethic – these people work incredibly hard.

One approach which I have found to be successful is to provide ownership in the business – a different approach from most companies which just provide a salary. The new graduates that I work with also get paid less than they might find elsewhere. If they could be getting £30,000 a year, I might only pay them £15,000. The difference is made up in their part of the ownership in the company when it is formed. Typically, after one year the graduates own 40 per cent of the company – if it takes two years to develop the solution they will get less ownership because I have to spend more money getting there, but it is a model I have had great success with.

After a year in these start-ups, the young entrepreneurs become strong, work-hardened, ready to take on anybody: they have ownership, they fight for their companies, they fight for their products. Success, after all, is not measured in the amount of hours put in, it is about commercial success – the amount of sales, and they develop a keen appreciation for that.

If society cannot take these young, well-educated people coming out of universities and turn them into the next generation of business people, where is the future? If we want a prosperous future we must have successful businesses. These are the businesses that grow and hire more people and pay taxes and provide ongoing employment. How else are successful businesses to be created?

I go to China four times a year and to India four times a year. I am a very frequent traveller to the USA, South America, Europe and Asia. I see the emergence of high-growth companies in China. I am aware of what is happening in the wider world around us! To be successful, businesses have to be aware of client requirements, and of emerging trends. In my area, Information and Communications Technology (ICT), the changes are coming thick and fast.

Rapid change offers the greatest opportunities, because when there is no change, the incumbent product or service provider has an inherent advantage with all the clients. It is only when there are significant, disruptive changes that the market opens up.

Right now, in many areas of ICT, there is a great deal of change worldwide – it is like going into a sweet shop with all these different opportunities! Currently I am involved in setting up four or five new companies a year. They are all extremely focussed. They are made up of new graduates. And let me tell you, most start-ups are not short term ventures. While it might take a year to a year and a half to come out with a product, it takes on average seven years to achieve sufficient success to realise a return on the capital investment, through a public offering or an acquisition.

But these talented youngsters are out there, and they have to fight hard for success in today's global environment. It may not be 'fair' that people in China or India get paid less than we do here, and so have a cost advantage in terms of creating and building products, but that is business today. Yet the combined population of those two countries is 2.6 billion people – a huge market that we too can fight for!

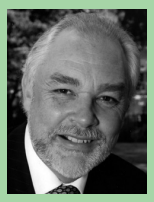
Those that have been in business for a long time, or have experience in some of the supporting professions, can also make an important contribution to encouraging business growth. They can set aside some time to help youngsters like these become the next generation of business people more quickly and more effectively. That is my model. We have innovative people – let's help them to become the next generation of business leaders! □

Sir Terry Matthews OBE FREng is Chairman of Wesley Clover, an investment management firm and holding company. He has founded or funded more than 100 companies, including Newbridge Networks which became a leader in the worldwide data networking industry. Sir Terry is also Chairman of a number of these private and publicly traded companies, including Mitel, Solace Systems and Counterpath, and he sits as a Director on the Boards of several others.

Addressing the meeting, Edwina Hart MBE CStJ AM, the Minister for Economy, Science and Transport in the Welsh Government, noted that the country had plenty of innovative young people, but the challenge was to turn that talent into real businesses. She agreed on the importance of tackling youth unemployment and stressed how the Welsh Government has invested in apprenticeships because they are the way of the future. The Minister added, though, that there was also a challenge in making graduates fit for purpose for industry. She argued that there is a duty for Government, the HE and FE sectors to look very closely what industry actually requires - not just core skills but also the specialist skills needed by the market. Governments must be prepared to take bold steps in supporting research and innovation, and be prepared to accept a proportion of business failures. She acknowledged that this might not be the traditional approach but it is the one needed in order to support entrepreneurship in today's business environment.

Professor Jeremy Watson CBE FREng FIET is Vice-President and Trustee of the Institution of Engineering and Technology (IET).

Patrick Kniveton FIMechE FIET is President of the Institution of Mechanical Engineers.



Professor Tim Broyd FREng FICE is Vice-President of the Institution of Civil Engineers (ICE)

Professor John Uff CBE QC FREng FICE is a barrister at Keating Chambers. He was a panellist during the discussions after the formal speeches.

Can Learned Societies – and particularly those in the engineering sector – act as catalysts for economic growth? This issue was debated at a meeting of the Foundation for Science and Technology held at the Royal Academy of Engineering on 24 September 2013.

Raising the bar

There are a significant number of Learned Societies representing the engineering sector, brought together collectively under two other bodies, the Engineering Council and the Royal Academy of Engineering. Professor Broyd for the Institution of Civil Engineers, Professor Watson for the Institution of Engineering and Technology and Patrick Kniveton for the Institution of Mechanical Engineers each explained the historical development of their organisations and how their founding visions had led to their current role and focus.

Patrick Kniveton, the President of the Institution of Mechanical Engineers, explained the purpose of the engineering institutions in the words of George Stephenson, in the founding statement of the Institution: "To enable Mechanics and Engineers engaged in the different Manufactories, Railways and other Establishments in the Kingdom, to meet and correspond, and by a mutual interchange of ideas respecting improvements in the various branches of Mechanical Science to increase their knowledge, and give an impulse to inventions likely to be useful to the world." He stressed the continuing relevance of these words, and especially the final phrase regarding 'inventions likely to be useful to the world'.

Professor Jeremy Watson, Vice-President , the Institution of Engineering and Technology, described the current landscape in which engineering – and its learned societies – operates, saying: "Engineering contributes £481 billion to the UK economy, employs 5.4 million people across half a million engineering companies and is key to the commercialisation of research and development leading to new products and services, new industries and new jobs. However we still need to attract a greater talent pool into engineering, with joined-up action to ensure we seize the opportunities at a national and international level (we need 1.25 million science, engineering and technology professionals and technicians by 2020)."

Growth

Yet while their members will all be focussed on growing their businesses both in the UK and abroad, growth is not formally part of the mission of any of them. Although, as Patrick Kniveton noted, the first President of the Institution of Mechanical Engineers, George Stephenson, had stated in his Presidential speech of 1847: "Unless the talent of England was concentrated it was not unlikely some of the continental talented men might take part of the business of the Country ..." So the threat of foreign competition was acknowledged from the outset.

A key role for individual bodies is in setting and enforcing standards for various grades of membership as well as fostering continued professional development and upskilling. As Professor Broyd noted: "We help economic growth by providing a set of standards for civil engineers and civil engineering. Individual people, individual companies will be working, hopefully, above those standards,

DISCUSSION

Official support for innovation

There is an important difference in practice between Europe and the USA. There, Government procurement policies ensure that valuable contracts are awarded to companies whose innovations have received Government assistance. However, this is not possible within the EU where public purchasing rules - public procurement above a certain threshold requires a competitive bidding process - precludes the adoption of such a desirable policy in the UK.

but we will provide a baseline set of understandings."

In terms of setting and upholding standards, Professor Uff noted that one role of every engineering institution is the drawing up of a Code of Professional or Ethical Conduct and the putting in place of mechanisms which protect the interests both of its members and the public. He recalled that this aspect came into sharp focus in New Zealand as a result of the Canterbury earthquakes in 2010-11 in which an inadequately designed building collapsed killing 115 people. The CTV building had been the subject of a report more than 10 years earlier which had revealed the inadequacies. The author of the report had followed the existing professional code but the report became "lost in the system" and the building remained a major risk. The report of a Royal Commission should, he added, cause all engineering institutions to review the adequacy of their own procedures.

Engineering the Future

The engineering profession has formed an alliance, *Engineering the Future*, to strengthen engagement with policymakers and support a thriving economy based on wealth creation and prosperity through engineering innovation. With a combined membership around 450,000 engineers, Engineering the Future is a broad alliance of professional engineering institutions and associated bodies. Leadership is provided by a core group of institutions: the Engineering Council; Engineering UK; the Institution of Chemical Engineers; the Institution of Civil Engineers; the Institution of Engineering and Technology (IET); the Institution of Mechanical Engineers; the Institute of Physics; and the Royal Academy of Engineering.

Engineering the Future also draws upon the expertise of Education for Engineering (E4E), the body which represents the engineering profession on education, training and skills.

www.engineeringthefuture.co.uk

Liaison

The Learned Societies have an important role in liaising with Government and other bodies involved in engineering. While not 'trade bodies' who lobby for particular outcomes or projects, they are able to provide impartial, independent, expert advice. This is sought not just by Government but by many other interested bodies such as the Research Councils.

To maintain close links with Government, many of the larger learned societies in the engineering sector maintain London headquarters, although Professor Uff questioned whether that was necessary in today's world especially given the location of members. But having a London HQ does not mean that the societies are London-centric. Referring to the ICE, Professor Broyd noted: "We also have a very vibrant and active network of regional groups throughout the UK – it is amazing how forthright members can be if they think things have become too London focussed, especially if they are in places like Scotland and Yorkshire, for example!"

Professional organisations such as the ICE, IET and IMechE make a very important contribution in providing a neutral ground where business discussions and strategies can form in a way that complements those generated on a direct company-company basis. This is particularly important for the medium size businesses. Professor Watson argued that, at the UK level, it is growth in the medium-size businesses that will make the big difference to employment (because the vast majority of people are employed in such businesses). Patrick Kniveton also stressed the importance of small and medium enterprises (SMEs) to the economy and the crucial need for actions and policies to enable SMEs to grow.

Building links

In an increasingly global market, the societies need to build wider links too. Professor Watson noted: "reports project that annual global output will more than double in two decades, from $78 trillion to $176 trillion. Three-fifths of that extra output will come from emerging or developing economies. The force behind this growth is the growing purchasing power of the middle classes, particularly in Brazil, Russia, India and China (the BRIC countries) and other emerging economies. Today, India and China account for a mere 5 per cent of global middle class consumption, while Japan, the United States and the European Union account for 60 per cent.

"By 2025, those numbers are expected to equalise. By 2050, they will have flipped. Supporting economic prosperity is not the only crucial role the engineering sector has to play in our future."

A further essential item for the Learned Societies and their engineering members is public engagement. If engineering is to transform the economy, then it can only be done when the public understands the benefits to be gained from training and employing a new generation of engineers. Patrick Kniveton concluded: "True change comes however when the 93 per cent of the UK population who are non-engineers and non-specialists start to take an interest in what we say. The key is to talk about what interests them and not just tell them what interests us." ☐

DISCUSSION

Reaching out to schools

While a greater awareness by Government and the public of the importance of engineering is welcome, more can be done. In particular, it is important to encourage more women to enter the profession; there are still far too few female chartered engineers. This might be helped if learned societies actively welcomed teachers into their membership and actively encouraged engineers to enter teaching - they are much needed.

The Royal Society of Edinburgh has completed an inquiry into digital participation. A meeting of the Foundation for Science and Technology held in Edinburgh on 13 October 2013 explored some of the issues being considered in the inquiry which, while focussed on Scotland, has general implications.

How can the benefits of digital access be made available to everyone?

Alan Alexander

The first point to make about digital participation is that infrastructure is not enough. The Royal Society of Edinburgh's Inquiry into Digital Participation[1] follows on from the infrastructure inquiry of 2010[2]. In addition to infrastructure, digital participation requires: access to skills, equipment and training; effective motivation; as well as a recognition by all sectors that they have not yet engaged effectively.

This Inquiry focussed on why people and organisations do, or do not, participate. A US Congress blog called The Hill neatly sums up the purpose thus: "The promise of the internet lies with investing in human capacity as much as with technological capacity."

The Inquiry has been overseen by a broad-based committee. It has collected and collated evidence from Scotland and elsewhere. It has carried out a number of consultations with follow-up round-table discussions in a number of cases. The committee collected opinions, gripes and case studies, some of which appear in the final report. There has been an emphasis on vulnerable and excluded groups largely because, *prima facie*, they could benefit disproportionately from engagement.

The committee has been acutely aware of the value of clearly-targeted recommendations which explain what needs to be done and sets out who needs to do it.

The Inquiry's agenda is wide-ranging. We want to understand what different people and groups mean by 'digital Scotland'. We want to explore the dividends for various sectors of society. We want to see what is happening to the digital divide. We want to be very clear about digital inclusion – why it is so important, how it can be encouraged. In addition, we want to identify the role of society and the state, including Government institutions, in encouraging digital inclusion.

Professor Alan Alexander OBE FRSE is General Secretary of the Royal Society of Edinburgh and Co-Chair of its Inquiry into Digital Participation. He was Professor of Local and Public Management at Strathclyde University. He was also Founding Director of the Scottish Local Authorities Management Centre. Professor Alexander was a member of the Commission on Local Government and the Scottish Parliament (The McIntosh Commission). He has been a member of the Economic and Social Research Council (ESRC) and of the Accounts Commission for Scotland.

Infrastructure

While infrastructure is not sufficient to ensure digital participation, it is certainly a necessary condition. Yet there are remote areas which still are waiting for reliable broadband. There is a problem, too, with percentage targets. If the target is 80 per cent, that means 20 per cent are left out. Percentage targets also tend to push providers towards the low-hanging fruit.

A further issue is how to increase participation in areas which have good infrastructure available but low take-up for other reasons. A report by Carnegie on digital non-participation in Glasgow pointed out the impact of multiple deprivation. The four areas of lowest participation were the four peripheral housing estates of the city. Citizens Advice, Scotland, did an excellent piece of work interviewing and surveying everyone coming into CAS offices seeking advice and help in applying for benefit over a two-week period. What was surprising was how high a percentage of these people were expected to apply online yet had no access to the internet, either because they did not have a device or because they did not have a broadband connection.

Non-participation

The reasons for non-participation are well known:

- lack of access;
- lack of equipment and the current cost;
- lack of skill – not knowing how to use the technology;
- lack of motivation.

The last of these is difficult to tackle. There are many factors affecting motivation and indeed confidence. A significant issue involves fear and risk: what will happen if I make a mistake, what will happen if I put information online but people steal it and use it for nefarious purposes? Media headlines do nothing to dispel those fears. Now, while risk cannot be

Digital Scotland

This Inquiry builds on the Royal Society of Edinburgh's *Digital Scotland* report. That concluded that Scotland must aim for broadband speeds of at least 16Mb/s by 2015, and should establish a Digital Scotland Trust to deliver and operate a backbone fibre infrastructure to bring high speed broadband to all communities. The issues were discussed at a meeting of the Foundation on 28 October 2010. A report on the debate can be found in *FST Journal* Vol 20 No 6, which can be accessed at: www.foundation.org.uk/Journal/Default.aspx

DISCUSSION

Online access for the disabled

The public sector does not always demonstrate a thorough understanding of the problems of the disabled in using online services. There is, too often, a lack of coordination – one might start off online, but then there are complex forms to fill in on paper, or a supplementary visit has to be made to an office to verify identity. There is plenty of scope to allow voluntary bodies to explore alternative ways of engaging particular groups of disabled in online services. Simpler technology is essential, though: instructions must be accessible, legible and understandable. Local authorities need to be much more imaginative in the use of public space for online purposes.

eliminated it can be managed and society needs to help people to do just that.

Access has to be ensured for everybody. This includes the itinerant and the homeless because they will have to apply online for benefit within the next few years. That necessitates a clear policy about the provision of secure places in public spaces where people can access the internet.

There should be learning opportunities for individuals (and businesses) because one thing that is quite clear is how the learning process accelerates once started. Tell an elderly person that she can talk to her grandchildren in New Zealand by Skype and interest will be awakened. Other opportunities can then be explored.

The digital dividend needs to be better demonstrated. Online participation promises: efficiency savings, especially for the public sector; a reduction in healthcare costs; better education and employment outcomes; as well as the availability of a wider range of goods at lower prices.

Communities

Digital participation can make a huge difference to people and communities that experience isolation. It can help enable independent living for an aging population, and foster social inclusion for scattered minorities.

Beyond the main urban areas of Scotland, there are many small communities whose very survival depends on small businesses continuing to trade, continuing to succeed. Yet, it is precisely the very small businesses who are least engaged and have very low understanding of the benefits of the digital age. A way has to be found of showing them the advantages to be gained.

Many small enterprises have an inadequate understanding of the costs, risks and opportunities associated with going online. They think it is much more expensive than it is in reality and they believe that they are expected to compete with Amazon if they go online. Even if they just use email or get themselves onto an online map, they can start experiencing the benefits. There is an urgent need for tailored entry-level courses for businesses.

Public access to public computers

The Inquiry found that one of the most likely places for people to find public access computers is in libraries. Unfortunately, the number of libraries is reducing significantly, meaning that provision is becoming increasingly sparse and involving longer journeys. However, in every community there is another suite of publicly-owned, publicly-financed institutions. These are in schools.

Computers in schools are used typically for a maximum of four hours per day, 35 weeks of the year. Yet no education authority in Scotland allows public access to school computer suites. There are many reasons for this, but the fact remains: these public computers are inaccessible to the public.

In Scotland we aspire to universal digital inclusion. To foster this, greater public access needs to be achieved and schools seem to be the most obvious option. In addition, if the digital divide is not to persist, there should be a target that minimum broadband speed should be 25 per cent of the median (and that target should be maintained as the median rises).

People go online for a wide variety of social and cultural reasons. They participate because they are motivated and do not if there is no incentive. There is therefore a need to discover what motivates particular groups of people to participate.

Bad experiences can produce fear, which is a 'negative motivation'. Transparency and clarity about how data is used and stored can help reduce that fear.

My colleagues and I on the Inquiry do not believe that the Scottish education system has yet caught up with the digital revolution and we perceive a lack of coordination of training initiatives. So, there is a need to provide basic understanding and skills, via a joined-up approach by training providers. SMEs need peer-to-peer support so that they can learn from those who are already on the path. And we believe that a 'trusted trader' approach, a sort of Kitemark for service providers (to give newcomers to the digital world the confidence that they will not get ripped off) will help some businesses and individuals take the plunge. □

1. www.royalsoced.org.uk/1058_SpreadingtheBenefitsofDigitalParticipation.html

2. www.royalsoced.org.uk/886_DigitalScotland.html

A role for local government in delivering the digital agenda

Lorraine McMillan

In response to The Royal Society of Edinburgh's earlier inquiry into public sector digital infrastructure, a Local Government ICT Board was established to provide leadership in this area. A strategy was launched at the start of 2013, with implementation now taking place. The Board includes Chief Executives of Councils, senior IT managers, Scotland Excel (the local government procurement organisation), The Improvement Service and the Scottish Government – a broad mix of people.

ICT in local government faces three main pressures in Scotland and these link to the participation agenda.

The first is cost. Budgets are declining,

in real terms at least. So there is a requirement to find ways in which IT can reduce costs in the public sector. Customer expectations, however, are rising. People want to access services 24 hours a day, seven days a week. This is coupled with an increasing demand for public services in general. For example, people in East Renfrewshire enjoy some of the longest lifespans in Scotland – so the area now has one of the fastest-growing over-85 age groups. Many of these people are still living independently but they need some support. This offers great opportunities – and demands – for digital technologies.

Digital Scotland

The vision of the national strategy *Digital Scotland* is to encourage people to access services online. The Local Government Board's strategy contributes to this and has three goals. More services are to be delivered online, the public sector should shape the delivery of this change and costs have to be reduced. We are working in partnership with Scottish central and local government as well as the NHS.

We want more people to use online services, but should that be offered as 'digital by choice', 'digital by default' or 'digital first'? Scotland is adopting 'digital first' which means that, while people will always be offered first a digital service wherever possible, there will always be alternative means available for those who cannot access them digitally.

There are wider pressures associated with the Digital Scotland programme: cities need to be connected, there is an economic imperative to be at the forefront of technologies. The country has top level universities, but for the future of the economy it needs students with excellent digital skills. So schools and nurseries are the real places to start that journey.

There are four areas where we are focussing our efforts on encouraging greater participation:

- poverty;
- access in rural areas;
- disability;
- age.

My own community, East Renfrewshire, is generally fairly wealthy, but there are pockets of quite extreme deprivation and poverty. These contrasts have to be taken into account in the roll-out of services. Digital access is just not affordable for some.

Yet innovative thinking is breaking down barriers. In Glasgow, a housing association is putting wireless into three tenements so that people can access it. While poorer residents may not be able to afford a landline (£16-£17 per month plus broadband), it is possible to get a pretty good mobile contract for £10 per month which includes access to the internet. If the wireless infrastructure is in place, people can then take advantage of online services.

There is good use of ICT facilities in libraries. Some people use libraries for access because they do not have a device at home. East Renfrewshire has a very wide training programme in its libraries, so no matter what age a person is, they can get training in how to use the internet. In poorer areas, libraries are packed with people doing just that.

People used to go to the library for a reference book, now we use the computer for reference – the same thing, just delivered in a different way.

There are free wi-fi zones in a number of public buildings, one in a park! It is actually inside the pavilion but the signal is so strong it can be accessed outside as well.

Lorraine McMillan is Chief Executive of East Renfrewshire Council. She joined the Scottish Development Agency in 1989 specialising in technology transfer. She then went to Scottish Enterprise Dunbartonshire in 1991, becoming Director of Enterprise and then Chief Executive of Scottish Enterprise Renfrewshire. As well as her East Renfrewshire Council role, she leads on the implementation of the Local Government ICT Strategy, focussing on getting more services on-line, reducing costs and enabling reform across the local government sector.

Poverty

Digital access can be used to address poverty. Take young mums who have a child at 16 or 17. Most of them use digital technology; they have been using it at school and they now have access to a phone. Most of them are on Facebook. In the Netherlands, there is a scheme which uses phones to access videos of good parenting techniques such as how to hold a baby correctly. The young mums would not have gone to a parenting class, but if their health visitor showed them how to hold the baby correctly and they could see it on video, they will make use of it.

There are challenges, though. There is a move in schools to 'bring your own device'. While children and young adults will be using computers in every class, they will no longer be going to a computer class as such. Now, when children start to bring their own device there are a number of security issues which have to be addressed. In addition, in some areas they will have iPads and computers and all sorts of phones but in the more deprived areas those devices will not be available. Equally, a child may not want to bring their device in because it is not as good as somebody else's. So there are many challenges for digital inclusion in education.

Rural areas

The national broadband initiative will give 85 per cent of Scots access to fast broadband although in some remote rural communities, people cannot access broadband at all. Yet people can be extraordinarily innovative. There are numerous accounts in the media of people in Skye and such places running really amazing businesses and finding ways to access broadband.

Aging

Local councils have a duty to look after residents with disabilities and we are starting to see digital as an enabler rather than a disabler here. For older people,

DISCUSSION

Digital education

Local authorities can be too optimistic about the effectiveness of digital teaching in schools. There is some excellent teaching, but the use by children of computers is often more sophisticated than teachers comprehend – and in some schools equipment is outdated. Good practice needs to be shared to ensure that best practice is understood and implemented throughout the country. An overall director for digital education for all schools should be considered. School online equipment should be available for public use. There may be some contractual and safety/security issues, but these are the sort of challenges which imaginative planning can overcome.

there is Telecare, where they wear alarm buttons in case they fall or are injured. This is now being linked to their smoke alarms as well which means the call centre can intervene to find out if they have burnt the toast or have a fire – in which case fire and rescue need to be called. That is really, really important. The plan is to extend this initiative to different sorts of sensors, enabling people to prevent or manage chronic illnesses while remaining in their communities.

While age is an issue in terms of digital participation, it is not always the oldest people that have a problem. I remember hearing about one elderly lady who was being shown very slowly how to use Telecare, to which she responded: "This is just like Skype I use to contact my grandson in Australia." In fact, the age group least able to use digital are the 50 to 60 year olds because they are too proud to say they cannot use it: so they say it is not suitable. When someone says the organisation or the community 'is not ready for it', they really mean they cannot use it and they have a real fear of it.

One of the issues, for older people, is getting devices that do not break. My 85 year old father-in-law has started using an iPad. He has never sent an email, he has never been technically trained, but iPads work for him, because we told him 'you can't break it'. It is also good because he can change the font size – his sight is not good and his hearing is not good, but with an iPad, it is possible to make adjustments so that the technology becomes more accessible.

In conclusion, it is important not to put people into arbitrary categories: the poor are not always excluded – some are but others are not. The public sector has a specific role in ensuring that people are enabled.

Local government can make a whole raft of initiatives available through local libraries to help people participate. The biggest enabler, though, is the school. I hope that every child in East Renfrewshire leaves school with very strong digital skills. The digital skills of our primary students are vastly superior to my own. Teachers are really keen to deploy new technologies and they must be supported in that. ❐

Representation and identity in a digital world

Alan Blackwell

In talking about digital participation, there are several key issues. How can a digital infrastructure allow a more effective delivery of services? Then, how does participation affect representation in a democratic society – because it seems to me that the nature of our society and our democracy is changing due to technology? There is also a need to consider the way in which young people can construct their identities through digital – digital is becoming a means of participation and self-realisation.

Service delivery

Taking a wider – in fact, global – perspective on service delivery, the GAVI alliance, funded by UNICEF, the World Health Organisation (WHO), the World Bank and the Gates Foundation, aims to vaccinate every child in the world. So far they believe they have vaccinated about 100 million, but the problem is that they cannot be sure. This is because, with a very complex supply chain, they do not have the data to verify their estimates. Their service is underpinned by substantial layers of inter-connecting infrastructure and the relations between them are not always clear. They drop off huge vaccine containers at airports but have very little knowledge about what goes on after that. They came to Cambridge for help because, they had concluded, "what is needed in order to finish the job is data".

Many people now do their grocery shopping online with the produce being delivered to the door by van. Yet the van does not come from nowhere, it is part of the infrastructure behind service delivery. And when people connect online, they are linking to a large infrastructure that often takes them away from participating in local organisations.

My parents in New Zealand use web-based services to talk to their granddaughter. Once again, there is a great deal of infrastructure behind that – and it is not neutral. Huge conglomerates like Apple, Google and Android lock customers into large industrial complexes.

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Representation

Colleagues in Cambridge are creating a system called Africa's Voices – it is quite a simple model. A single laptop computer is given to a radio station in an African community and connected to the network so the laptop can receive SMS messages. The radio presenters often discuss local government issues and policy. The community does not have internet access but it does have mobile phone coverage. Listeners can contribute to the public debate via SMS messaging. In addition, these responses can be compared to the same debates being held in another eight countries across sub-Saharan Africa.

In this example, there is no digital deployment at all, but there is participation nonetheless. By collecting large amounts of data, collating and analysing it, government services can be developed to respond to the needs of disenfranchised communities.

However, there is a problem here: this process is not democratic. This is just about crunching numbers and seeing what comes out. We need a new kind of journalism communicating information about public data to their audiences. Indeed, we also need new kinds of scientists, new kinds of public analysts too.

People involved on initiatives like Africa's Voices are committed to 'deliberative democracy'. Big data has the tendency to anonymise information and to deal with people as 'averages over a population' – it is actually less participatory than the democracy we already have with

DISCUSSION

Making connections

Full digital participation can connect people and bring them closer together, creating communities and in turn reducing isolation and exclusion. Trust grows if people work together; their fears of risk are reduced. The development of online communities could also affect the relationship of individuals to government. However, special interest groups would have to ensure that they were not just representing the views of a small but digitally-literate minority. Conversely, those who might not otherwise have the means to object to a policy may find it easier to express concerns. No doubt a rolling referendum on every policy would be problematic. It is an open question whether democracy would suffer or benefit from universal digital participation.

local newspapers and local radio stations.

The next questions is: into whose hands should all this data be entrusted? People are becoming very nervous about the fact that their data are being collected and passed on to people who may not have their best interests at heart. Perhaps what is needed is, instead of surveillance, '*sous-veillance*': the people under the system should be able to look at those making the rulings and then make their own interventions and reversals. Maybe the security cameras should be *inside* the Council Chambers rather than outside?

Self-realisation

There is a village called Budikote in India which has a village radio station. However, this does not broadcast via radio waves: instead, there are speakers in the trees which carry the output to the community. So this is far from any digital infrastructure.

A group of British workers have helped them connect to the internet and make use of some of the digital devices that allow people to create programmes about their lives. In this process, the villagers were very ambitious. They did not want to make a radio programme; they wanted to put a video on You Tube showing what their lives were really like.

The method was to use a very simple application – a mobile phone – because that was the only way to send data out of the village (there was no broadband nor landline). The villagers used the camera on the phone to take still pictures and then put these together with a soundtrack to produce a really compelling video on You Tube.

Media production, rather than media consumption is key to how people construct their digital identities in the digital world. Now the BBC is a great media producer and its content is largely publicly-owned. There is no reason why people in the UK should not have access to that in order to change content or produce it for their own use.

The BBC has, in the past, developed digital tools for people to create their own content. The BBC Micro kick-started a whole industry. Today, there is a new generation device called a Raspberry Pi. It costs £25 and provides a computer which can be given to children (or adults) and used to make content.

The challenge is to enable content that would be as satisfying today as that produced with a BBC Micro 25 years ago. Nowadays, even relatively low-income households have access to X-Boxes and Playstations where they play complex visually-appealing games. Even with all the marvellous things packed into the Raspberry Pi, it is not possible to play a game like Call of Duty.

Where to from here?

There are, however, some bright signs for the future. As one example, the Minecraft game is not as high-resolution or violent as Call of Duty. It is a relatively simple game – a bit like digital Lego. Yet many children have become amazingly enthusiastic about it and they build things in it. Players have to make tools following types of recipes – you have to educate yourself in this, so you build the world as you play it. The Swedish authors of Minecraft are enthusiasts for the Open Source movement, so many players will actually download the source code and write their own programmes: in this way they change the way the game works.

Because of the democratic nature of building your own world, people use it to explore different kinds of world. And young people are very interested in subverting conventional media holders. A group of students have made a version of the Hunger Games in Minecraft with the same characters so they can act out the movie by themselves. There is also a Minecraft version of Farmville, which is a Facebook add-on.

There are, then, technologies that enable our young people to be creators, not just consumers. People can take ownership of digital technology by making it to suit themselves. However, it is by no means all good news.

Many of the developments that empower people are challenging corporate interests, media interests and intellectual property (IP) interests. Large corporations and the digital providers are not providing services that deliver rewards to the people who make a creative and inclusive society. The large established players are not encouraging people to create their own content.

A key question, then, is: alongside creating an infrastructure for digital participation, how do we create or revise legislation to remove embedded obstacles to participation in our existing networks?

Service delivery is important but it needs to take account of self-determination alongside infrastructure. Representation involves deliberative democracy, not just big data. To help people realise their own ambitions and identity, they must be given opportunities for creativity and empowerment with digital technology. ☐

DISCUSSION

Affordability

Questions of cost and affordability remain. While average household expenditure on communications is estimated at £100 and it is consequently assumed that everyone can afford a little more for broadband, the funds available per household in deprived areas is around £25 - which renders extra expenditure for broadband untenable. There is scope for making tablets cheaper - Tesco now offers one for just £100. The public sector should be driving prices down too. This would not just help the deprived; small SMEs with low profit levels, who cannot risk expenditure without seeing a quick return, would also benefit. So, in turn, would the communities where they are based. These small enterprises are often based in villages where they provide employment and form the mainstay of community prosperity. If the businesses fail, the community suffers as well. Remote areas, and the marginal craft industries located there, are particularly vulnerable.

The Committee on Climate Change has set tough targets for the UK to reduce carbon emissions over the next two decades. This will involve decarbonising the energy systems. The challenge and the potential solutions were discussed at a meeting of the Foundation for Science and Technology on 27 November 2013.

Counting the costs of decarbonisation

James Smith

Climate change is a dangerous threat that society needs to tackle. But this is not a problem of technology. The technology exists to get the job done. It is affordable too – the cost is about one per cent of GDP. Nonetheless, at a global scale, that means spending £700 billion per year to decarbonise. A great deal of good work could be carried out in other areas with that amount of money. So it needs to be spent wisely by finding the least cost routes.

However, we are desperately short of time. The accumulation of greenhouses gases in the atmosphere has to be reversed, quickly and significantly. Yet because of the scale and inertia of the global energy system, change is not easy. Leadership is required at individual, institutional and political level, both nationally and internationally.

A time critical problem

Although the economics and science of climate change are complex, the arithmetic of climate change is simple and stark. This is an order of magnitude problem. The global economy needs to decarbonise by a factor of 10. Broadly speaking, by the middle of the century, one unit of economic output has to be achievable with one third of the energy input required today and, in addition, one unit of energy has to be produced for one third of the carbon emissions of today. Overall, that would decarbonise our economy by a factor of 10, the level of reduction needed.

However, a recent report by Price Waterhouse Coopers shows that the energy system is far from the needed trajectory. The carbon intensity of the global economy has been declining at an annual rate of just 0.7 per cent. If that trend continues, the carbon budget of the atmosphere will be exceeded by 2034 or thereabouts. To avoid climate damage, the rate of decarbonisation of the global economy needs to accelerate to 6 per cent per annum. That would produce the factor-10 savings by mid-century, with zero emissions by the end of the century.

Dr James Smith CBE is Chairman of the Carbon Trust. He retired from Shell in April 2011 after seven years as Chairman of Shell UK. He had worked for Shell in Malaysia and Brunei, a number of Middle Eastern countries and on Shell businesses in the USA. In addition to his role as Chair of the Carbon Trust, James is Chair of the Advisory Board of the Grantham Institute on Climate Change at Imperial and LSE, a Trustee of the Science Museum and a past President of the Energy Institute.

Finding the least cost pathway

So what are the cheapest solutions that will deliver the required goal? This is a systems problem that requires systems thinking.

It is possible to estimate levelised electricity generating costs. The operators of the new Hinkley Point nuclear station have agreed a price of £92.5 per MWh. Non-mitigated gas-fired production (CCGT) is around £60 and gas-plus-CCS about £100, but there are significant sensitivities around gas pricing. Offshore wind is estimated at between £100-135 per MWh. These are estimates from the Department for Energy and Climate Change (DECC). Since current wholesale prices are around £60, it is clear that low carbon electricity is going to be more expensive.

It is not yet clear which technology is best. So, option-management makes sense as does diversification in the face of long term risk and uncertainty.

Systems costs versus levelised costs

From a systems point of view, levelised costs form just one input to a more complex calculation. Maximum electricity demand occurs after dark in the winter. Electricity demand at midday in the summer is a lot less.

The problem is that the capacity has to meet the maximum demand points. Just as London Transport has to plan for rush-hour demand at the beginning and end of the day, so the electricity system must have dependable capacity for the points of maximum demand on a cold winter's evening in January. What, then, happens to the surplus capacity during the summer?

In particular, if large amounts of non-renewable capacity (built for winter demand) leave over-capacity in summer, where is the need for solar power? The question is not how levelised costs

DISCUSSION

The economics of diversity

The EU is seeking to impose a target for renewables, but this is inconsistent with the UK Government's belief that a technology-neutral stance is necessary to ensure system optimisation. The key to cost-effective carbon reduction is flexibility and diversity among fuel sources. The price of individual fuels such as gas will vary significantly and cost changes mean that some technologies become less or more cost-effective. Generators need to be able to shut down plants which become uneconomic and switch resources quickly to other technologies. Demand levels may be less volatile, but we need to be clearer how, in the long term, they are to be managed.

Phase	Technology maturity and market instruments
to 2017	Technology demonstration – renewables obligation and 'administrative' price setting
2017-2020s	Technologies maturing - some technology-specific auctions
2020s	Growing technology maturity – technology-neutral auctions
late 2020s	Technologies mature enough and carbon price high enough to enable competition without intervention

Table 1. Phases of UK electricity market reform as set out in the Energy Act. Source: DECC policy overview, Dec 2012.

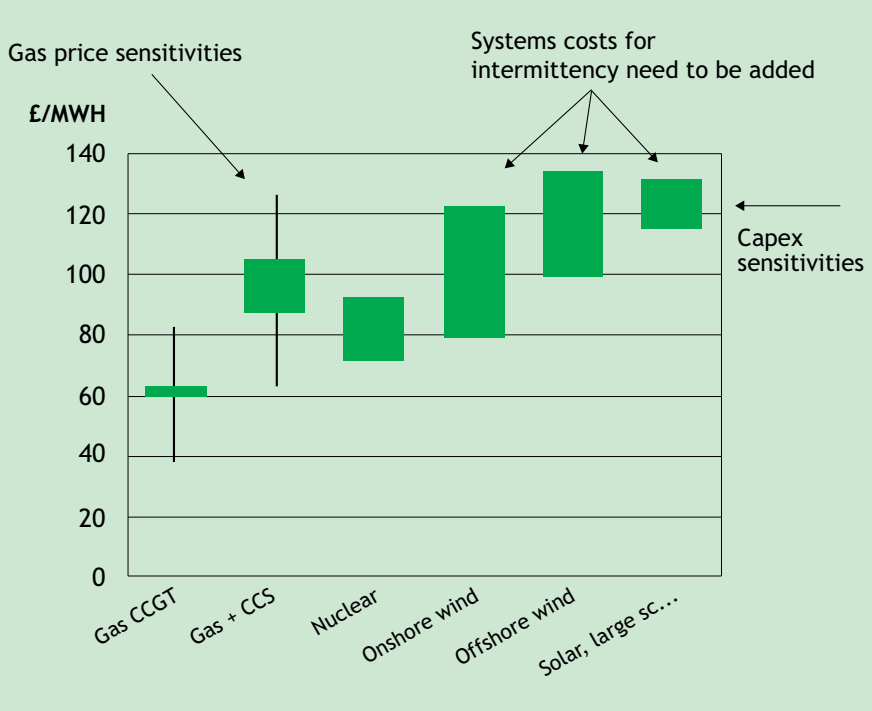

Figure 2. Levelised electricity generating costs, with sensitivities. Projects starting pre-construction work by 2019 (gas CCGT excludes carbon costs). Source: DECC, July 2013.

compare, it is rather how does the total cost of solar compare with the cash cost of running that idle capacity. Load shifting and energy storage also come into the overall systems evaluation, though.

Evaluating systems costs

The solutions to systems costs evaluation will vary across the globe. In Japan or Texas or Southern California there is a huge electricity demand at midday for air conditioning, when solar is at its best.

Finding the right answer for any country will involve significant, complex modelling. There is also the question of who should carry out the modelling and who should make the decisions on which technologies to choose. There are a number of agencies and academic institutions who have the capability, but which one should have the responsibility?

Dealing with inertial forces

Looking at global analyses of energy supply, while there has been enormous growth in renewable energy sources, this has been dwarfed by the increase in fossil fuel usage in absolute terms. The challenge of taking early action to reduce the amount of carbon dioxide going into the atmosphere means we cannot ignore fossil fuels.

The energy system has a great deal of inertia built into it. It takes a long time to develop, mature and deploy a technology to the point at which it has a material impact on the total system.

Taking a phased approach

There are four phases to the innovation process – the 'four Ds': discovery, development, demonstration, deployment. The UK is currently in the demonstration phase for those technologies that will make a difference over the next 15 years. These include technologies such as offshore wind, biomass, nuclear and Carbon Capture & Storage (CCS). Technologies such as marine are at earlier stages of development.

The Energy Act sets out a phased approach and gives timescales. Low-carbon technologies in the demonstration phase need financial support through mechanisms such as the Renewables Obligation. As technologies mature, technology-specific auctions can be run. With increasing maturity as the 2020s progress, it should be possible to run technology-neutral auctions. Longer term, with a carbon price, investment decisions can be left to the unseen hand of the market.

There is a logic in the mechanisms that are being set up (although they are rather complex). Yet when fossil is competing against renewables it makes an awkward mixture. Perhaps a system based on Return on Investment (ROI), offered on a competitive basis as they do in some parts of the USA, might be a better means of ensuring we get the right sort of systems outcome. This may be a mechanism for the future. ☐

Creating an affordable energy system for the UK

David Clarke

Electricity demand goes up and down over the course of the year. UK generation capacity is currently about 94 Gigawatts (GW). Yet electricity is only part of the equation. On one Saturday morning (16 December 2010), heat demand went up by 132 GW in one hour as people got up and switched on their gas boilers all at the same time. The electricity network could not have coped with such an increase. It might be possible for it to do so one day: the pumped-storage plant at Dinorwig in North Wales can deliver the ramp-up rate but the system would need 100 such plants to deliver the power requirement.

How much should the UK pay to meet carbon reduction targets? Most commentators agree that it should be 'around 1 per cent of GDP'. I would add a caveat: if the systems are not optimised, then that number does not just creep up, it doubles immediately.

System basics

There are a number of factors that all contribute to the development of an energy system for the future in the UK. First of all, there needs to be an adequate understanding of the drivers for this kind of development, in terms of costs, supply capability and capacity, infrastructure needs and investor requirements. There must be clear market and value opportunities for investors and consumers, as well as a supportive and stable policy environment.

One factor that is often left out of consideration is consumer support. Yet this will be crucial for whatever plans are adopted. A lack of support can eliminate technologies overnight – nuclear in Japan, Carbon Capture & Storage (CCS) and nuclear in Germany, etc.

If the system needs to accommodate different options, it needs to retain that flexibility as the programme moves forward. Also, there must be innovative incentives for industry to actually invest in the UK – and not just Government subsidies.

The Energy Technologies Institute has built a tool called ESME – Energy System Modelling Environment. The critical thing about this is that it integrates future development of power, heat, transport and infrastructure. Looking just at electricity generation is not sufficient to create a cost-optimised approach.

Dr David Clarke FREng is Chief Executive of the Energy Technologies Institute. Previously he was Head of Technology Strategy at Rolls-Royce plc. He has been involved in collaborative research and development of advanced technologies for over 20 years. At Rolls-Royce he led a range of technology groups including their Advanced Materials development activities and the corporate Strategic Research Centre. He is a Board member of the SPECIFIC Innovation and Knowledge Centre.

ESME is a tool which gives robust, evidence-based assessments to the question of how much it costs to decarbonise the UK's electricity supply. Among the items that recur time and again as preferred solutions from the ETI modelling work are: nuclear; CCS for both fossil fuels and biomass; offshore renewables; bioenergy feedstocks; gas; and improvements in efficiency. Broadly-speaking, these are 'no regrets' choices for the next 10 years. They deliver benefit at relatively low cost in the short term, almost irrespective of the likely long-term energy future.

However, to deliver these six items in the most cost-effective way and contribute to our energy future, the system has to be optimised around them. This leads on to thinking about how to create the infrastructure that supports this.

The easiest example to give is Carbon Capture & Storage. To deploy CCS, there will need to be a CO_2 pipeline network across the UK. If the current plan is to build power stations with fossil fuel supply in the middle of the UK, the pipeline will have to extend all the way to the coast and beyond. It might be more sensible to site the power stations by the coast in the first place.

Then there is innovation which needs to be applied across all the technologies to improve performance and reduce costs. Finally, there needs to be some innovative thinking about business models to make sure that they too are optimised to deliver value from the system.

Planning for the future

Take two very different scenarios of what the future might look like. In the first, the UK works to achieve an 80 per cent fall in emissions by 2050. In the other, no target is set other than building the lowest-cost system for the country's energy needs.

The ESME model suggests that the likely resulting systems start to diverge in the early 2020s. By 2050, in the '80 per cent reduction' scenario, there has been extensive construction – some 140 GW of generation capacity (compared with our current 94GW). With no targets, generation capacity actually reduces to less than we have today. So there is a big difference in capacity requirements in these alternate futures.

The 'no targets' 2050 world is very straightforward: fossil fuels are the cheapest, most widely available resources and they give security in terms of diversity of supply. In a world of targets there is more diversity is efficient: fossil fuels with CCS; a large tranche of nuclear power; hydrogen; and renewables. Critically, in this picture of our future, CCS and nuclear

DISCUSSION

Public awareness — or ignorance

Consumers may not be willing to accept the costs associated with the carbon targets - even if these are as low as 1 per cent of GDP. There may be a need for carbon reduction, with dangers from increasing emissions, but the public do not see the urgency in cutting back now. The public understanding of risk has always been poor. Climate change is not seen as a crisis, to which people have to respond by action. Rather it is dismissed as something which might happen sometime in the future.

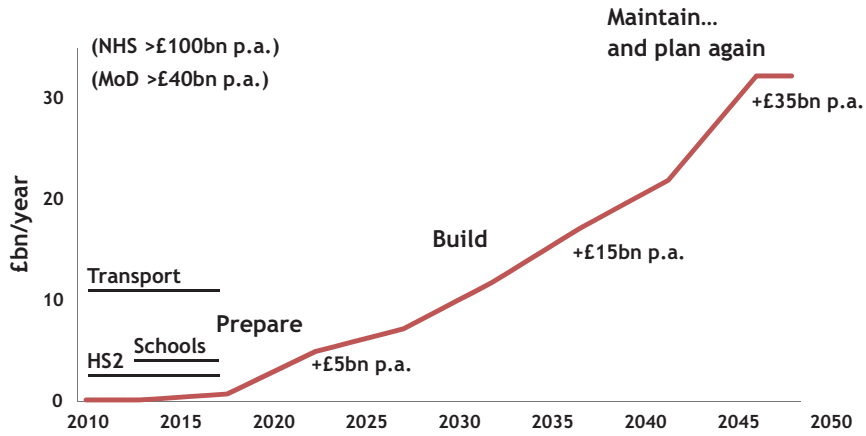

Figure 1. Incremental capital investment in energy infrastructure

are the mainstays of electricity supply.

Making a choice

Until about 10 years from now, the two paths look quite similar, but from the mid-2020s they diverge. So there is a decision to be made within the next decade. Of course, the reality is not likely to be so black-and-white, it will probably lie somewhere in between these two scenarios.

For the low-carbon route, there are additional costs in implementing CCS, nuclear, offshore wind, improving building efficiencies, etc. If we do all of those things, in an efficient but practical way, we are likely to see additional national costs of around £300 billion between now and 2050 – the extra 1 per cent of GDP often quoted as the cost of meeting the UK's 80 per cent CO_2 reduction target.

However, the ETI's model allows us to calculate the impact of different policy decisions regarding technology choices. Take out nuclear and it is likely to cost a further £50 billion to reach the low carbon target. With no CCS, the additional expenditure is of the order of a further £200 billion.

The ESME modelling shows that there is a decision to be taken by the mid-2020s. It highlights that the key technologies are almost certainly nuclear and CCS and they must be part of national policy programmes. There is also a cost associated with delay: a five-year deferral of nuclear and CCS would add about £5 billion per annum to overall system costs.

Capital costs

To create a system which will deliver 80 per cent cuts in emissions, capital expenditure would probably come in at about £5 billion a year until the mid-2020s (Figure 1). After that, it rises to about £15 billion and with a final roll-out of infrastructure in the 2040-50s, it increases further to around £35 billion a year.

The initial costs to 2025 are relatively small when compared with other Government commitments such as the Health Service or Defence but the long-term annual investments levels are comparable.

Innovation can play an important role in mitigating these higher costs. Validating and implementing innovations which are part of very high cost, long-life capital assets tends to be inherently expensive so actions have to be targeted carefully.

First, the financial conditions have to be right. What level of carbon price would be necessary to make innovation in these areas cost-neutral? The ETI's analysis identifies three broad brackets. There are a number of technologies which, to all intents and purposes, have a 'zero carbon price' to be cost effective – energy efficiency, energy storage, biomass for heating. There is then a further group which, with a carbon price of between £30-50 per tonne, become viable. Big asset plants – nuclear, CCS, bio-energy for power – start to fall into that bracket.

Offshore wind, marine technologies and electric vehicles need much higher carbon prices to make them cost-neutral, or industry must find a way to drive costs down. For offshore wind, the ETI is looking at long blades and floating platforms, which should bring the costs down to levels that would be compatible with nuclear (around £50 per tonne of carbon, perhaps a little higher).

Cost-reduction is not the only challenge facing low-carbon energy, though. Look at the current debates about CCS – these revolve around investor confidence. The investment community needs to become comfortable with the scale of the investment and the potential returns of some of these major technologies.

Then there is the business model. Even for efficiency in buildings, it is still a struggle to get consumer pull. Energy storage at a distributed scale does not yet have a market mechanism to incentivise it.

What then needs to happen over the next 10 years? It is vital to keep options open on the future delivery of electricity. Government, industry, finance, academia, all have to work together to identify the right options and associated costs. The levels and timings of investment need to be understood. Critically, though, the initial costs over the next decade are relatively low.

Finally, back to innovation. Engineers tend to look at the technological innovation phase and sometimes miss the need for business model innovation. We also need to consider how we can engage consumers in such a way that they commit to this future and understand the implications, not least from a price point of view. ☐

Delivering a low-carbon future

Sandip Verma

In order to meet the UK's carbon abatement targets, around 60-80 Gigawatts of new electricity generating capacity will need to be built by 2030, of which some 40-70GW will come from low carbon technologies.

The Government has embarked upon one of the most radical overhauls of the UK's energy infrastructure and markets since privatisation in the 1980s. Electricity Market Reform (EMR) encompasses a package of measures to incentivise the replacement of aging electricity infrastructure by a more diverse and low-carbon mix at the lowest possible cost to the consumer. The estimated electricity investment between now and the end of the decade is up to £100 billion (£55-65 billion for generation and around £35 billion for networks).

Electricity market reform

The most recent Impact Assessment estimated that annual household electricity

bills would be 6 per cent (£41) lower on average over the period 2014 to 2030 under EMR, compared to reducing emissions through existing policy instruments[1].

The EMR package is calculated to generate benefits of around £10.7 billion up to 2030 and could support as many as 250,000 jobs in the energy sector. There are also potential benefits to the supply chain: the Government considers that open and competitive supply chains will drive down the cost of low-carbon generation over the long term and result in lower energy costs to consumers.

The long-term vision for the electricity market involves a decreasing role for Government and a move to a market where low-carbon technologies compete on price.

The EMR is a market-pull mechanism, but incentives to deploy technologies can only be achieved with the market push of technology innovation. We need to have lower costs and more efficient technologies.

Innovation

UK innovation in low carbon technologies provides opportunities for the economy. The DECC Carbon Plan recognises that innovation is essential to meet the UK future energy needs. Investment in innovation now will improve the affordability of the technologies we deploy in the future, reduce bills for householders and businesses, and strengthen energy security by offering a range of technology options for the UK to deploy.

Indeed, recent growth figures show that green investment is paying back handsomely. The UK now has a share of the global low-carbon goods and services market worth more than £120 billion annually, equivalent to 8 per cent of GDP, and accounting for a third of the recent growth in the UK economy.

The Energy Technologies Institute's Energy Systems Modelling Environment (ESME) suggests that savings to the UK economy through innovation over the next 40 years could be up to £600 billion.

The two key challenges in maximising opportunities involve finance and risk.

The Baroness Verma of Leicester is Parliamentary Under-Secretary at the Department for Energy and Climate Change (DECC). Prior to this, she was a spokesperson for the Cabinet Office, International Development, Women and Equalities and Business Innovation and Skills. She was an Opposition Whip from 2006-2010 and then Government Whip following the 2010 General Election. A successful businesswoman, Lady Verma started her first business at the age of 19 in high fashion, supplying high street multiples.

Innovators have to secure financing throughout the development journey. This is a particular challenge for smaller businesses that are not generating sufficient revenue to borrow from banks and are developing complex technologies which are not widely understood.

The other challenge is risk. New technologies have unpredictable risk. Reducing risk will quicken uptake and encourage further private investment.

Collaboration

Collaboration between Government and innovators is essential. Innovation gives the UK a competitive advantage in global markets. Yet, the private sector alone cannot deliver the innovation we need. DECC's innovation programme is projected to save the UK up to £160 billion in energy costs in the period up to 2050. That in turn could leverage over £100 billion of private investment, adding up to £89 billion to GDP.

Between 2011 and 2015, the programme is supporting 150 entrepreneurial companies developing low carbon technologies. The UK has the most offshore wind deployed anywhere in the world. Analysis indicates that by 2050 offshore wind innovation alone has the potential to deliver cost savings of £45 billion and business creation for the UK worth £18 billion.

The Government is supporting this important sector through the Offshore Wind Component Technologies Scheme. With a budget of up to £15 million, it aims to help companies to test and demonstrate devices and to develop component technologies that can cut the costs of offshore wind energy in the run up to 2020 and in the subsequent decade.

We are also investing in Carbon Capture and Storage (CCS) innovation, helping to develop new carbon capture technologies, including processes and chemicals. The Netpower project aims to reduce the costs of power generation by over 20 per cent compared with current achievements and capture all of the CO_2.

In 2013, DECC announced funding for a number of innovative technologies through the 'Invest in Innovative Refurbishment' programme, including: £19 million for energy storage: £5 million to integrate UK nuclear research infrastructure: and £10 million for energy efficiency technologies.

We are also working across Government with other funders of innovation, including the Department for Business, Innovation and Skills (BIS) and the Energy Technologies Institute, to maximise the impact of UK public sector funding for low carbon technologies through the Low Carbon Innovation Coordination Group (LCICG). Together we will provide £1 billion between 2011 and 2015 to directly support energy innovation.

Targeting support

To determine how best to identify and target our support, the LCICG has published a series of Technology Innovation Needs Assessments (TINAs). The TINAs focus on meeting targets at lowest cost and boosting economic growth. These reports cover technologies from domestic buildings to energy storage and next generation nuclear.

The LCICG is now building a strategy to help guide our innovation programmes and determine our priorities over the next decade. The strategy will provide greater confidence to the energy sector, reducing risk and helping to align investment.

The Government plays a key role as an enabler. Our scientists, engineers and entrepreneurs are the sources of innovation, though, and it is their ideas that will reduce energy costs, create jobs and stimulate growth. □

1. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/268202/Delivery_Plan_IA.pdf

DISCUSSION

Cutting demand

While great emphasis is placed on supply issues, there has been little discussion of the demand side. Much greater efforts need to be made to encourage consumers to restrain their demand. A full roll-out of smart meters will help, particularly to moderate peak demands and discourage unnecessary use of power. But it is behavioural change that is really needed. There are insufficient incentives for retailers and other business consumers to reduce energy use. Education is key, but community pressure should not be under-estimated (it was effective in the case of waste collection). Communities could come together to promote demand reduction, exerting peer-pressure to encourage a change in habits.

The UK has undoubted strengths in research and technology. But how can these be maximised for the benefit of the UK and its people? The issue was discussed at a meeting of the Foundation for Science and Technology on 13 November 2013.

Maximising UK strengths in research, innovation and higher education

John O'Reilly

The remit of the Director-General, Knowledge and Innovation at the Department for Business, Innovation and Skills (BIS) covers three main areas. There is the research base: the seven Research Councils, UK Space Agency, etc. Second, there is the Innovation Directorate, which includes responsibility for the Technology Strategy Board, the Intellectual Property Office, the National Measurement Office and a number of other bodies. Then there is Higher Education: we have funding and policy responsibility for England but, not least because responsibilities in the first two areas are UK-wide, we have a need here too for a UK-wide perspective.

While it is quite convenient to look at these areas separately, it is important not to overlook the fact that they are inextricably linked and they work together. I would suggest that no nation could sensibly decide to be good at only one of the three – research, innovation or Higher Education. To be excellent at any requires commitment to excellence in all three; they are so inextricably intertwined and mutually supportive to the point of symbiosis.

Sir John O'Reilly FREng is Director General, Knowledge and Innovation, at the Department for Business, Innovation and Skills (BIS). Sir John has oversight in BIS of the Research Councils, the Technology Strategy Board, Quality Research (QR) funding of universities and other research and innovation policy and funding and for Higher Education in England. He was Vice-Chancellor of Cranfield University from December 2006 to February 2013. Prior to joining Cranfield he was Chief Executive of the Engineering and Physical Sciences Research Council (EPSRC).

Higher Education

Let us consider three international rankings for universities: the Jiaotong (which is produced in Shanghai) and the *Times* HE and QS scales. Although universities move up and down depending on the particular ranking system, the most striking fact is that only two countries are represented in the top ten of all three: the UK and the USA. The UK is very strong indeed and, when adjusted for GDP or population, stands out by a considerable margin.

Yet it is not just in the long-established, famous seats of learning where this country excels. A recent study by the *Times Higher Education* and the *Guardian* ranked the top 100 universities in the world that are less than 50 years old. On that measure, too, the UK heads the table: our newer universities come out very strongly when measured against their peers around the world.

Research

The Chancellor has said publicly that he wants Britain to be the best place in the world to do science (and when he says 'science' he is referring to the full spectrum of knowledge creation through research: science, engineering and technology, of course, but also, importantly, the social sciences, the arts and humanities, etc). The UK has maintained substantial ring-fenced funding for scientific research through difficult times. Funding is awarded competitively which is part of the basis of its continuing success.

Science, of course, is international. Goethe said that science and the arts belong to the whole world. Barriers of nationality vanish before them. Chekhov said there is no national science, just as there is no national multiplication table. That is a way of underscoring the importance of international engagement. For many years it has been the case that, for almost all countries, Britain has been the first choice for collaboration in frontier research after the USA.

The numbers are well known and speak for themselves. The UK has 1 per cent of the world's population, funds about 3 per cent of the research that is done across the world, produces around 6.4 per cent of the academic papers and achieves 11.6 per cent of the world's citations. That last figure rises to about 15.6 per cent if the standard is the most highly-cited papers.

Turn that into yield per unit of currency invested and the UK massively outperforms any other country.

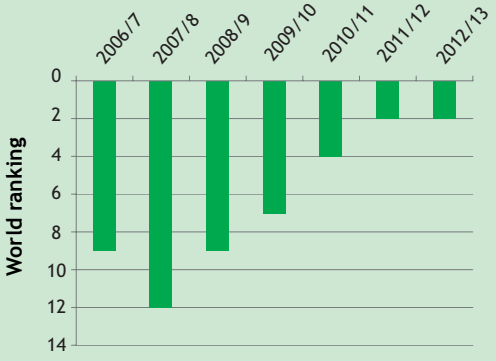

Figure 1. UK world ranking in university-industry collaboration. Source: World Economic Forum

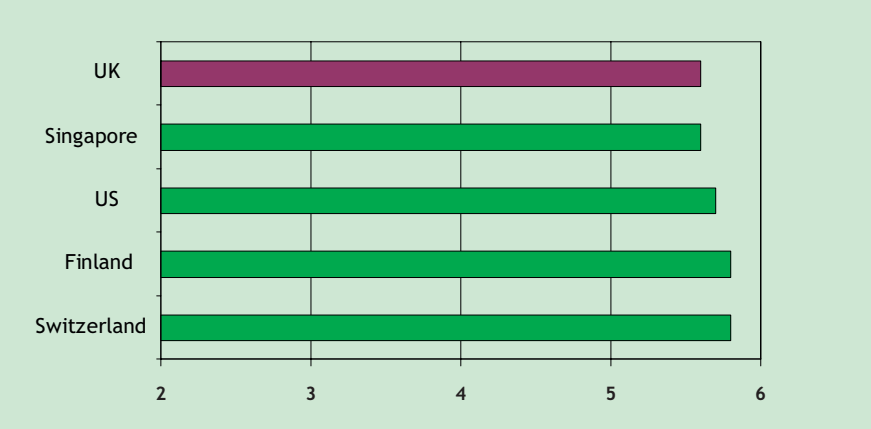

Figure 2. University-industry collaboration rankings 2013-14 on a scale of 1-7. Source: World Economic Forum.

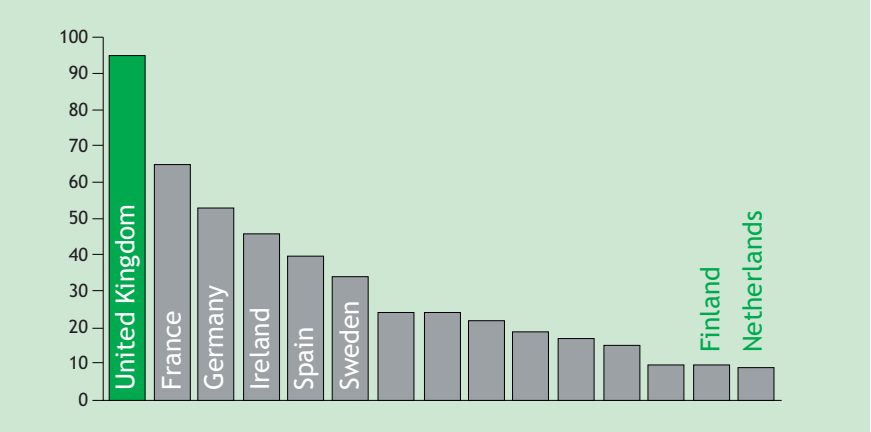

Figure 3. Number of R&D Foreign Direct Investment projects by EU destination country, 2002-2006. Source: BIS.

Innovation

There is a view in circulation that we do rather well in research but that we are not as good at innovation. However, I think that there has been some quite remarkable progress in recent years. Looking back to 2007-8 and before, we were about twelfth in the world, using the World Economic Forum's measure of the extent of collaboration between academia and industry in research. By 2013, on the same measure we were second.

So it came as a surprise when the latest data showed we were fifth. Looking more closely it becomes evident that the top five countries in this area are performing almost identically. In other words, we are now firmly in the leading group worldwide, as judged by the WEF.

We also are very good at attracting R&D investment from global businesses. And despite difficult economic conditions, business R&D has held up reasonably well in recent times.

GE, headquartered in the USA, has its own global innovation scorecard and the UK sits in the top quartile, along with the USA (countries are not individually ranked). According to the World Intellectual Property Organisation, the UK again ranks very high – and IP rights are probably as much a condition for innovation as innovation itself.

One remarkable achievement in 2010 was the Government's commitment to maintain the science budget despite the prevailing difficult economic circumstances. The 2013 Spending Review has shown that for the immediate future there will be continued pressure on public spending. Even so, there was still an extra £185 million allocated to the TSB, putting it on a firm forward trajectory.

There has in fact been very consistent Government support for the science, innovation and higher education agenda. Looking forward, I believe it is time, collectively – across Government, across industry and more widely in the country – to stand back and form a view of what 'good' (by which I mean 'excellent') looks like in the 'knowledge triangle' of research, innovation and higher education. A clear, shared, view of what is appropriate here to help us achieve the kind of economy and society that we wish and need to have would serve us well. □

The criteria for measuring value

Ben Ritchie

In thinking about maximising the value of UK strengths, the obvious question is to enquire what is meant by 'value'? It is important to be clear on this. There are four broad categories where we might look to see whether the country is capturing that value: the creation of jobs; the creation of products; the creation of profit; and the creation of human capital and skills. Higher Education in particular is not just concerned with creating patents, it is also about creating people.

In assessing value, there are many things that are more intangible than monetary value and which are actually more important: health, happiness, enjoyment, pursuit of public life. Those are all things that research, innovation, science and technology can help to deliver, so these need to be included in any assessment of value.

Creating the right environment

What measures need to be taken in order to establish an environment which encourages the creation and capture of value? There is, in fact, a remarkable convergence of thinking on what needs to be done. The Fabian Society (not a natural ally of the CBI or the Department for Business, Innovation and Skills) sets out four main considerations in a recent paper: energy costs, infrastructure, long-term thinking and a fair deal for well-trained, highly skilled employees. Those four concepts can also be found in the CBI's *Raising the Bar* paper[1]. There may be disagreement on details, but the fundamental framework and ideas are broadly shared across a range of parties.

The consensus is there about the things that need to be done. These include: an infrastructure rewarding high-quality, well-trained people; the provision of

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good quality educational establishments; an environment that reduces regulation and encompasses a favourable tax environment. These are not radical, crazy policies, they are mainstream. The pace at which those things are realised may vary under different proposals but the structures and framework are very much consistent.

Manufacturing has declined as a percentage of GDP because services has grown so much more. Today, with deflationary pressure from the emerging world and the huge productivity gains delivered by the increasing use of technology, it is hardly surprising that a first world, highly developed, highly sophisticated economy like the UK should focus more on services than manufacturing.

That notwithstanding, UK corporates have done surprisingly well over the last 20 to 30 years. Yet although they have adapted to new circumstances, they have not innovated as much as they could. Aberdeen Asset Management invests in a number of the top UK engineering firms. They have all, without exception, followed the same 'cookie cutter' strategy, focussing on: value; margin; return on capital employed. They do not invest in heavy machinery, they operate capital-light assembly structures and they push the manufacture of components and raw material costs down the supply chain (preferably to another country where manufacturing does not cost very much). Add to that approach a barrier to low-cost entry from competition through a network of services and spares provision and these businesses have a model which has served them exceptionally well over the last decade.

However, while this approach has enabled successful adaptation to a highly challenging economic and business environment, it has not resulted in the kind of radical innovation and disruptive change that is needed to create a really vibrant science and technology sector within the UK.

Industrial engineering – aerospace and defence, chemicals – has created substantial value compared with the wider stock market index over the last 15-20 years. This has been achieved, though, at huge cost: manufacturing jobs have declined from 7 million to just over 3 million since 1970, while household names like ICI, Rover and British Steel have disappeared – some have been taken over and dismembered, some have simply disappeared in the face of overwhelming forces of international competition. The UK has always operated an open-door policy to takeovers and as a result it has probably suffered in terms of R&D spending as a percentage of GDP.

Across the wider economy

Innovation and adaptation have taken place in the UK economy, not just within heavy industry but across a wide range of areas which have faced significant change.

From being a largely print-based company with Penguin, the FT and a very, very successful education business based around textbooks, Pearson has become the leading online digital education company in the English-speaking world. By undertaking a whole decade's worth of change, it has been able to create huge amounts of value through the development of a really innovative and different business model.

The Lloyd's insurance market, again, is another British institution which has risen, phoenix-like, from the flames of asbestos claims and under-capitalisation 20 years ago. Today, it is the leading specialist insurance market in the world, driven by technology but also by research (into risk, risk management and client assessment). It is probably the fastest-growing area in the City of London.

However, the FTSE All Share Index, in terms of technologies, of industrials, medical technology or pharmaceuticals, lags behind most of the other major developed markets in the world. Take the recent IPOs Twitter and LinkedIn: these have market values of around $24 billion and $26 billion respectively. The most valuable British technology company, ARM Holdings, is worth less than Twitter according to its stock market valuation. This is extraordinary given the value of the processor and chip designs that ARM produces.

Apart from ARM, it is difficult to find many companies of any material size within the technology base; even something like ASOS, which one might consider to be a UK version of Amazon – a low-cost retailer – has a market value of just over $7bn compared to Amazon itself which is valued at well over $100 billion.

Here in the UK, we have struggled to find and back those really innovative and break-through companies. One may debate whether LinkedIn or Twitter is sustainable, but that innovation and cutting-edge change has not really been found in this country.

A matter of culture

I believe the biggest problem in the UK is one of culture. We are a fundamentally conservative country. We do not take a long-term, constructive view when it comes to investing. The Kay Review[2] argues that we need investors prepared to commit to risk with a long-term view if this country is to have a culture that will support real, radical innovation. This is because the reality is that seven or eight out of every 10 start-up businesses will fail.

This conservatism is not confined to funders, though. It is also apparent in the corporate world where CEOs will not put money behind radical, new innovation. I do not know the reasons for the decisions by Rolls Royce to abandon its research into fuel cells and to discontinue its work on wave power, they may well be perfectly sensible commercial decisions.

DISCUSSION

Educating for success

Are we being complacent about the success of our education system? Outstanding research success and the reputation of our universities is rightly celebrated but overall our education system is not functioning in a way which will support research success in delivering value. While 90 per cent of children in Germany study mathematics in the Sixth Form, in the UK the figure is only 20 per cent. In higher education, there is still much to be done to encourage interdisciplinary working and, above all, to equip students and researchers with business skills and an understanding of business priorities

DISCUSSION

A risk averse culture?

Innovation is severely constrained by the risk averse culture of the UK. Investment managers need to take a longer view of financial return. A common complaint from start-up companies is the failure of financiers to provide adequate capital for development; this leads to promising companies being sold to the USA where further capital was available. To some degree, this may be inevitable because the pool of capital in the USA is so much deeper which affords more opportunities for risk taking. Universities and Government must be prepared to risk negative publicity from the failure of projects. There is a lack of motivation in the Civil Service (and in Government generally) to be seen to be innovative. Innovation is difficult, can result in failure and can take resources from other areas.

Yet the sums involved were relatively modest. It is another example of a great company, with a great deal of cash on the balance sheet, which is not prepared to invest in radical change for the long term. Unfortunately, we see that all the time in the UK.

One business that does take the long-term view (and not a business associated with a great deal of innovation or technology) is Primark. This is a business owned by Associated British Foods, itself largely owned by the Weston family. It is almost certainly the only company in the FTSE 100 that would have the patience to take a small Irish supermarket and turn it into one of Europe's leading discount retail businesses. It has been an astonishing success.

The company has been opening stores in Spain at a phenomenal rate, just when most people are closing them. It is a company prepared to invest through economic cycles, taking a long-term view, adapting and changing according to the way the economy is moving. Innovation is not always about technological progress.

The acid test

This wider view of innovation and its relevance to economic success needs to be constantly borne in mind. Being too narrow and prescriptive in focussing on an arbitrary divide between manufacturing or services, etc, is to miss the point. The acid test is whether an activity is innovative, whether it involves R&D, whether it is forward-thinking – and whether it will create value.

As a society we must think long and hard before setting rigid targets about how we rebalance this or that aspect of the economy. We should be much more concerned with overall aggregate achievement than being pleased because manufacturing has not shrunk as a percentage of GDP. To achieve this through neglecting other parts of the economy would make absolutely no sense at all.

John Maynard Keynes talked about how a failure of an attitude of mind was a critical factor behind the Great Depression. Warren Buffett has made the point that if investors had started in 1900 and invested in the US Stock Market, they would have gone through two World Wars, the Great Depression and the assassination of a President – and still enjoyed exponential returns. Those prepared to take risks will reap rewards and those that are prepared to take a longer-term view and embrace that risk-bearing culture will, I believe, derive great value for this country.

1. http://www.cbi.org.uk/campaigns/industrial-strategy/raising-the-bar-report

2. www.bis.gov.uk/assets/biscore/business-law/docs/k/12-917-kay-review-of-equity-markets-final-report.pdf

How Higher Education can deliver value to UK business

Geoff Rodgers

Higher Education is concerned with research innovation, producing graduates that are ready for tomorrow's jobs, creating new knowledge and supporting the UK economy. Yet the Lambert Review in 2003 estimated that only about 16 per cent of businesses were accessing information from HE. Lambert identified a whole range of issues from businesses and universities about how well (or otherwise) they work together and therefore how public benefit could be created from the work of universities.

He talked about poor R&D investment in the UK compared with other G7 countries. He emphasised the importance of knowledge transfer, as well as the importance of building relationships and capacity. He talked of 'significant cultural change' needed within HE (which has indeed been taking place since the report was published).

Lambert said there was much still to be done, and he was right. He talked about the barriers encountered when universities talk to industry. Some 50 per cent of companies reported deficiencies in customer service as the biggest problem in dealing with universities – and industry still complains about that today. Business also complains about difficulties in finding out who does what and who to talk to (I sometimes find the same problem within my own institution!).

Universities are still accused of being too aggressive over IP rights.

Different approaches

There is an essential tension between some of the reward mechanisms; academics are encouraged to produce high-quality papers and this is not always compatible with initiatives that support public benefit. This can create false drivers for academics to prefer one type of activity over another, and that is not necessarily good.

From the university's point of view there are other issues: industry is often unwilling to pay for costs on research projects. It can be necessary to use public funding in order to get industry to participate in projects – which is an issue when building consortia. Working with business involves lengthy and complex negotiations. Partnerships are difficult

to maintain when industry has a more rapid turnover of staff than occurs in universities.

At base, universities are driven by excellence in research, while industry is looking to create products and, ultimately, deliver profit.

When partnerships work they can be absolutely tremendous, but a huge amount of effort has to be put in to unlock the benefits of high-quality research for business.

Addressing the challenges

Universities have changed significantly over the past five years, but clearly there are still issues around blue-skies versus problem-solving research. Disciplinary silos remain barriers to interdisciplinary teams.

The advent of funding to support interactions between universities and business interaction has been an important step forward. Studies suggest that every pound going into Higher Education Innovation Funding (HEIF) yields typically between £6-8 (sometimes more) value to the UK economy.

Businesses are investing in universities: Brunel is one of a number that have developed long-term partnerships with major corporates. However, universities find it more demanding to interact with the small- and medium-sized enterprises (SMEs) which make up such a large part of the UK economy.

Policy

The policy landscape has been evolving very quickly. The arrival of the Technology Strategy Board (TSB) and the notion of creating research programmes that meet, directly, the needs of SMEs and industry has been a major step-change in the delivery of public benefit from research. The European Commission's Research for SMEs Programme and a number of similar initiatives have mirrored that approach. Brunel is engaged in sizeable and substantial research programmes funded and supported through the EU programme which deliver a great deal of value to SMEs.

Professor Geoff Rodgers is Pro-Vice-Chancellor (Research) at Brunel University. His main responsibility is to lead the University in the next stage of its research development, and ensure that it sustains a diverse and evolving, vibrant, research community. He has championed the university's open access archive and its publication database, as well as developing strategic partnerships for research with a number of research and technology organisations. He chairs the London Higher Research Excellence Group made up of the research PVCs of the universities in London.

The emphasis on articulating the public benefits of research and the public benefits of universities, more generally, has been critical in HE. The Research Councils' work on *Pathways to Impact*, together with the Research Excellence Framework (REF) case studies on public benefit and impact from the Higher Education Funding Council for England (HEFCE) have already, in my view, changed the culture.

The Catapult Centres represent an important new approach, one that our competitors are following. Other initiatives run by HEFCE, such as the Catalyst Fund and the UK Research Partnership Investment Fund (UKRPIF) have allowed universities to catalyse existing relationships into larger programmes which deliver benefits.

The decision of Universities and Science Minister David Willetts to allow business access to the fruits of the research from UK universities is an important one. Universities are working hard to ensure this happens. This has to be the right way to proceed and will help universities widen the impact of their research.

Impact

In terms of impact agenda, we are asking academics to consider the needs of the user right at the start of the research process, to involve users in the design of the research programme and to work with them throughout the research programme. This is to ensure that the research will ultimately be of benefit to them. Indeed, we are even asking blue-sky researchers to ensure that they understand how their work might be used so that the research programme is designed accordingly.

The Witty Review[1] identified a number of areas where universities might do better – better cooperation with Local Enterprise Partnerships (LEPs), better exchange of information between universities and industries and, particularly, working harder with SMEs.

Businesses could be much more involved in the totality of the university's agenda, from the co-design and joint delivery of programmes, taking students on work placements, influencing the product both in terms of the research and also in terms of the graduates involved: in short developing relationships that can bear fruit across a range of areas.

One example of the way in which this engagement is developing is a project involving Brunel with three other universities, as well as The Welding Institute, Network Rail and BP. It is funded by HEFCE and by the Regional Growth Fund. The aim is to develop a National Structural Integrity Research Centre – like a mini-Catapult Centre – based near TWI in Cambridge. It has significant public investment and addresses a major societal challenge. New innovation will be created around an important challenge but the project provides an environment where students, particularly postgraduates, can be educated. There is a 10-year plan for this project and as a university we see ourselves working in this area for the next 20 to 30 years.

We became involved in this project because of the opportunity provided by an industrial partner. We already have 20 to 30 academics working in this space where five or six years ago we had very few. Within three or four years we will have double that number. This is a user-driven initiative in which the industrial partners took the initiative, coming to us to discuss a new way of working.

DISCUSSION

Innovation in larger businesses

Large companies are traditionally reluctant to sponsor and fund radical R&D. If absorbed into the mainstream organisation, R&D departments tend to become less radical; kept separate they may be ignored, or starved for funds. The right balance between operational expenditure and R&D is a perennial problem in any company; it is the job of the CEO to get the balance and organisation right, as circumstances change. It is also the responsibility of the CEO to monitor how foreign companies handle innovation and to understand how to globalise successes.

We have a similar large-scale project based on a long-term, 10-year relationship with Jaguar Land Rover and Constellium, looking at advanced casting technologies. With several million pounds of funding from EPSRC, it is a unique national scale-up facility for light metal casting.

Our own Experimental Techniques Centre (ETC) has provided materials characterisation services for 350 SMEs over the past 10 years. About 50 of those firms have worked with us since, following that initial service.

They came with a problem, which we fixed by characterising a particular material's qualities. Then they came back again for something else and we developed a relationship with them over time. Most of these relationships lasted between six and 12 months.

In this way, we can draw in SMEs, provide them with useful services, perhaps do some contract or collaborative research with them to help them with a particular problem. Then they will go on their way again and will not be back until they need us again.

That is one way in which a medium-sized, research-intensive university can work quite effectively with SMEs. We offer a unique range of services – in this particular case, materials characterisation equipment – that SMEs can access direct from us.

Looking forward

What more can be done? Well, universities in general can try to produce more industry-ready graduates, taking a long-term view on what types of graduate might be needed over the next 20 years or so. In this way, we can develop graduates for the future, not for yesterday's jobs.

The areas identified in the Government's Industrial Strategy sectors are particularly helpful for universities in steering us to look at where we should be educating people and where we should be doing research. However, we also need to equip graduates with transferable skills in order to ensure that they are ready to enter the world of work. And that means adding more emphasis to some of the 'softer', transferable skills that employers in these sectors say they want.

Many institutions, including Brunel, are developing 'innovation hubs', to harness the entrepreneurial zeal that graduates have, to help them develop their ideas and, if those projects look really promising, help to take them to market. A significant number of graduates start their own businesses and the hubs can support that activity.

Maximising the impact of research

All institutions are having to look at what they are doing, how they maximise their strengths in the light of what is happening in the outside world. They have to identify opportunities and discern how they might work with industry better.

At Brunel, we are trying to bring people together around themes to address major societal challenges. We have chosen to reorganise our whole institution around three: energy futures; material manufacture; and health and society. To do this we are forming teams of 150 to 200 academics in each area.

We want to develop two or three very long term relationships with key industrial partners on these three themes. We believe we can then add a great deal of value to some of our partner companies, helping them innovate and providing them with the graduates that they are asking for.

We are also focussing on working with SMEs through intermediaries. We have learnt, over time, that working direct with SMEs in some circumstances is quite demanding for universities. We are, therefore, exploring the potential of working with them through other means – for example, with supply chains.

We have, for example, been working with Marks & Spencer together with a number of people who supply them. That is a good way to work with a corporate which has a chain of SMEs behind it. Engaging with the whole chain can be very productive.

Research and Technology Organisations (RTOs) and LEPs are also very effective at working with SMEs, so building relationships with them can streamline relationships. Instead of trying to work with a very large group of SMEs at the same time, suitable intermediaries can help us maintain and develop links over time. □

1. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/249720/bis-13-1241-encouraging-a-british-invention-revolution-andrew-witty-review-R1.pdf

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

Policy choices for the reduction of bovine tuberculosis (TB)

2 April 2014

Adam Quinney, Farmer and former Vice-President, National Farmers Union
Professor Rosie Woodroffe, Senior Research Fellow, Institute of Zoology, Zoological Society of London
Dr Miles Parker OBE FSB, Senior Research Associate, Centre for Science and Policy, University of Cambridge
Professor Chris Gaskell CBE, Principal, Royal Agricultural University

Turning knowledge into value - adding value to the marine sector from research and innovation

10 March 2014

Professor Ralph Rayner, Sector Director - Energy and Environment, BMT Group
Professor Ed Hill OBE, Executive Director, National Oceanography Centre
Professor Rick Spinrad, Vice-President for Research, Oregon State University. President-Elect, Marine Technology Society
Professor Richard Clegg, Managing Director, Lloyd's Register Foundation (*panellist*)

The challenge of communicating the uncertainty in risk estimates to decision makers

5 February 2014

Sir Mark Walport FRS FMedSci, Government Chief Scientific Adviser, Government Office for Science
Tom Bolt, Director, Performance Management, Lloyd's of London
Judith Hackitt CBE, Chair, Health & Safety Executive
Dr Michelle Harrison, CEO, Government and Public Sector Practice, WPP (*panellist*)

The economics of decarbonisation of the UK electricity supply – how much are we prepared to pay to meet carbon reduction targets?

27 November 2013

James Smith CBE, Chairman, The Carbon Trust
Dr David Clarke FREng, Chief Executive, Energy Technologies Institute
Baroness Verma, Parliamentary Under-Secretary, Department for Energy and Climate Change
Sir David King KB ScD FRS HonFREng, Foreign Secretary's Special Representative for Climate Change, Foreign and Commonwealth Office (*round-table discussion*)
Ian Simm, Chief Executive, Impax Asset Management (*round-table discussion*)
Dr Bernie Bulkin, Director, Ludgate Investments Ltd (*round-table discussion*)

Maximising the value of the UK strengths in research, innovation and higher education

13 November 2013

Sir John O'Reilly FREng, Director General, Knowledge and Innovation, Department for Business, Innovation and Skills
Ben Ritchie, Senior Investment Manager, Pan-European Equity, Aberdeen Asset Management
Professor Geoff Rodgers, Pro-Vice-Chancellor for Research, Brunel University

Digital participation: how can digital access be made available to everyone?

31 October 2013

Professor Alan Alexander OBE FRSE, Deputy Chair, Royal Society of Edinburgh Inquiry into Digital Participation
Lorraine McMillan, Chief Executive, East Renfrewshire Council
Dr Alan Blackwell, Reader in Interdisciplinary Design, Computer Laboratory, University of Cambridge

Improving the career paths for MSc and PhD students, and postdocs

17 October 2013

Dr Steven Hill, Head of Research Policy, Higher Education Funding Council for England
Harry Armstrong, PhD Student, Babraham Institute, Cambridge
Dr Helen Ewles, Research Associate, Department of Pathology, University of Cambridge

Cyber security: how secure are UK organisations from cyber theft of IP?

16 October 2013

Chief Scientific Adviser, Centre for the Protection of National Infrastructure (CPNI)
Hugh Eaton OBE, National Security Director, Cisco UK
Professor John V McCanny, Director, Institute of Electronics Communications and Information Technology, Queen's University, Belfast

Raising the bar - can learned societies and professional institutions particularly the engineering institutions do more to contribute to economic growth?

24 September 2013

Professor Tim Broyd FREng FICE, Vice-President, Institution of Civil Engineers
Professor Jeremy Watson CBE FREng FIET, Vice-President and Trustee, The Institution of Engineering and Technology (IET)
Patrick Kniveton FIMechE FIET, President, Institution of Mechanical Engineers
Professor John Uff CBE QC FREng FICE, Barrister, Keating Chambers (*panellist*)

Maximising the use of public data - should research and publically acquired data be made more accessible?

10 July 2013

Professor Geoffrey Boulton OBE FRS FRSE, Chair, Royal Society Inquiry into Science as an Open Enterprise
Professor Sir Nigel Shadbolt FREng, Chairman and Co-Founder, The Open Data Institute
The Rt Hon David Willetts MP, Minister of State for Universities and Science, Department for Business, Innovation and Skills
Professor Sheila M Bird OBE FRSE, Programme Leader, MRC Biostatistics Unit, Institute for Public Health, Cambridge (*panellist*)

Can university-business collaboration be used to maximise short-term economic growth and reduce unemployment levels in Wales?

3 July 2013

Professor Colin Riordan FLSW, President and Vice-Chancellor, Cardiff University
Sir Leszek Borysiewicz FRS FRCP FMedSci FLSW, Vice-Chancellor, University of Cambridge
Sir Terry Matthews OBE FREng, Chairman, Wesley Clover
Edwina Hart MBE CStJ AM, Minister for Economy, Science and Transport, Welsh Government

Cities of the future - science, innovation and city management

19 June 2013

Steve Quartermain, Chief Planner, Department for Communities and Local Government
Sir David King KB ScD FRS HonFREng, Chair, Future Cities Catapult
Richard Bellingham, Director, Institute for Future Cities, Strathclyde Business School, University of Strathclyde
Sir Mark Walport FRS FMedSci, Government Chief Scientific Adviser, Government Office for Science

Celebrating the centenary of the establishment of the Medical Research Council - What should be the research priorities for medical research over the next twenty-five years?

22 May 2013

Dr Sydney Brenner CH FRS, Senior Distinguished Fellow, Crick-Jacobs Center, Salk Institute for Biological Studies
Sir Paul Nurse PRS FMedSci HonFREng, President, The Royal Society and Director, Francis Crick Institute
Sir Keith Peters FRS FMedSci FRCP FRCPE FRCPath FLSW, Emeritus Regius Professor of Physic, University of Cambridge
Dame Kay Davies DBE FRS FMedSci, Director, MRC Functional Genomics Unit and Associate Head of Division of Medical Sciences, Department of Physiology, Anatomy and Genetics, University of Oxford (*panellist*)
Sir John Savill FRS FMedSci FRSE FRCP, Chief Executive, Medical Research Council
Rt Hon David Willetts MP, Minister of State for Universities and Science, Department for Business, Innovation and Skills

The Armitt Review of the UK long-term infrastructure project pipeline

16 April 2013

Sir John Armitt CBE FREng, Chair, The Armitt Review of the UK Long-Term Infrastructure Project Pipeline
Professor Brian Collins CB FREng, Head, Department of Science, Engineering, Technology and Public Policy, University College London
Tim Yeo MP, Chair, House of Commons Select Committee on Energy and Climate Change

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