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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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contents

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Public 'less informed' about science

A survey by polling organisation Ipsos-Mori shows that while there is an increasing appreciation for science amongst the public, people nevertheless feel less informed about the topic.

The Public Attitudes to Science 2011 survey found that 82 per cent of respondents agreed that "science is such a big part of our lives that we should all take an interest" and 86 per cent said they were amazed by the achievements of science. These proportions have been steadily increasing since 2000. Participants were similarly positive about the potential impact of science on economic growth.

However, 51 per cent of people felt they see and hear too little information about science, compared with 34 per cent in 2008. Similarly, 56 per cent did not feel well informed about scientific research and developments, compared with 43 per cent three years ago. Two-thirds of people also agreed that scientists should listen more to what ordinary people thought.

Sir Paul Nurse, President of the Royal Society, said: "The fact that people want to know more about what scientists are doing presents a big challenge for us. Scientists have not always put enough emphasis on having conversations about their work with the general public. Keeping science behind closed doors is not an option and talking at people is not good enough either. Where issues are controversial we have to find out what it is that bothers people and address those concerns.

"The survey shows that people recognise that scientists want to make people's lives better, we perhaps sometimes need to listen more and to be better at explaining what we are trying to do and what the benefits and risks will be."

Public Attitudes to Science Survey 2011 was commissioned by the Department for Business, Innovation and Skills. The survey is carried out every three years and this is the fourth in the series. For the 2011 survey, Ipsos MORI interviewed 2104 UK adults aged 16+ between 11 October and 19 December 2010.

www.ipsos-mori.com/pas2011

Presentations and audio from the events held by the Foundation for Science and Technology can be found on the Foundation's website at: www.foundation.org.uk

Chief Scientific Adviser appointed at the Treasury

The Treasury has appointed Dr James Richardson as its first Chief Scientific Adviser, ending its status as the sole major Department without a CSA. However, Dr Richardson will combine this role with his existing responsibilities as Director of Public Spending and Chief Micro-economist within the Treasury.

He is a prominent member of the Government Economic Service, leading on the GES cross-cutting analytical development of appraisal techniques to inform spending decisions. The GES is supported by the Government Economic and Social Research (GESR) team. According to the Treasury, Dr Richardson is "therefore well-placed to ensure joined-up natural and social science policy advice". He holds a doctorate in economics from the London School of Economics.

The Chair of the Science and Technology Committee at the House of Commons, Andrew Miller MP, welcomed the appointment. He said: "This is good news. It is anomalous that the Treasury has, until now, been the only Government department not to have a Chief Scientific Adviser."

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

Using procurement to stimulate innovation

In 2009-10, public procurement was valued at over £236 billion, approximately 15 per cent of GDP. Government is "the single largest customer" in the UK. This magnitude of expenditure provides enormous potential to stimulate innovation and encourage economic growth – a potential which, according to the House of Lords Science and Technology Select Committee, is not being realised.

Having investigated Departments across the board and the Department for Transport in particular, the Committee, in a report published on 25 May, calls for a "root and branch" change in attitude towards adopting innovative solutions throughout the public sector. It wants the Government to find innovative procurement solutions to achieve better value for money, promote economic growth, and encourage the translation of scientific research into innovative goods and services.

Committee Chairman, Lord Krebs, said: "Government spent over £236 billion in 2009-10 on buying goods and services. This represents a significant opportunity for public sector organisations to use that money not only to encourage innovative solutions to procurement problems but to achieve better value for money and to stimulate economic growth."

The report also recommends appointing a Minister to take overall charge of procurement and innovation, and a Minister within each Department with specific responsibility for innovation and procurement in relation to departmental spend.

www.publications.parliament.uk/pa/ld201012/ldselect/ldsctech/148/148.pdf

Procurement was debated at a meeting of the Foundation on 22 June. A report will appear in the next issue of *FST Journal*.

Moving towards a single European patent

Ministers reached further agreement on the details of a unitary patent at the EU's Competitiveness Council in Luxembourg on 27 June. Ministers agreed on the number of translations which applicants need to file to get their patent. They also agreed on the technical details of the patent itself. As a result it will be easier and cheaper to register patents.

Speaking at the Competitiveness Council in Luxembourg, UK Intellectual Property Minister Baroness Wilcox said: "The creation of a single European patent and patent court is crucial for UK industry. We support a European patent system which gives real benefits for business, consumers and the economy. It is vital to offer businesses the same access to patent protection in their home market of Europe, as competitors in the USA, China and Japan enjoy in theirs."

Agreement of these two regulations, one establishing the patent and one on the language regime for the patent, will reduce the cost of translating patents in Europe by up to 80 per cent says the UK Government. This will also allow any company or individual to protect their inventions through a single European patent valid in 25 countries.

An independent review of Intellectual Property and Growth by Professor Ian Hargreaves found that establishing a unitary patent would remove IP barriers between EU countries and could increase UK national income by over £2 billion a year by 2020.

Hargreaves review: www.ipo.gov.uk/ipreview-finalreport.pdf

Continued on page 4.

Thick or Thin? The funding dilemma

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 is Chief Scientist at IOP Publishing.

Shortly after the beginning of World War II, food rationing was introduced. As the war went on, some rations were reduced and for most of that period the butter ration was 2oz per week per person. My mother devised a system whereby each member of the household (there were five of us) was taxed 1oz, to allow for treats such as an occasional butter-based pastry. Each of us was therefore left with 1oz which was carefully guarded and labelled.

Every week I faced a dilemma: did I use this amount on four rounds of bread which would meet my needs for a couple of days, or did I spread it so thinly that it could see me through a whole week? I never really resolved this dilemma, but I usually went for the thick option.

A similar dilemma faces university research in the UK today, given that we are at best entering a period of 'flat' funding which will last for the foreseeable future. If 'islands of excellence' are to be funded, the money has to come from somewhere: that 'somewhere' appears to be the top research universities (mostly within the Russell Group). The 14 or so UK universities among the international 'top 100' cannot understand why the quality-related (QR) funding awards arising from the 2008 Research Assessment Exercise (RAE) appear to put them at a disadvantage. By the same token, less research-intensive universities feel that their distinctive contribution should also be valued and that where members of such institutions are researching at the highest level, they too should be supported.

To understand how the current situation has arisen, we must go back to the RAE 2001 and before. Units of Assessment (UoA) were graded 5*, 5, 4, 3(a and b), 2 and 1. To achieve 5*, at least 50 per cent of the research had to be carried out at a level of international excellence and none at 'sub-national' level. Even a small amount of sub-national work would lower the grade to a 5. The fundamental problem here was that the volume factor was *inside* the brackets: it meant that all staff were assumed to be working at the same level. So, woe betide an outstanding individual who happened to be in a Grade 3b department: he or she would get no QR support. However, researchers working at sub-national level would still receive funding if they happened to be in a Grade 5 department.

The Roberts Review

This state of affairs appeared unjust and the suggestion by Sir Gareth Roberts that a research profile rather than a single grade would be a more equitable way of distributing QR funds was accepted. Roberts proposed five levels of excellence which would inform QR funding:

- four-star (4*): quality that is world-leading;
- three-star (3*): quality that is internationally excellent;
- two-star (2*): quality that is recognised internationally;
- one-star (1*): quality that is recognised nationally;
- unclassified: quality that falls below the standard of nationally recognised work.

The funding ratio announced in 2010 was 9:3:1:0:0 for the respective grades, and clearly aimed to promote concentration. After 2011, selectivity will be further increased by reducing QR funding for 2* research.

The reason why an outstanding institution such as Imperial College is QR-funded less favourably than pre-Roberts is because not all staff achieved grades of 4* or 3*. By contrast, the University of Lincoln increased its research income from £266,000 to £1.9 million, an increase of 628 per cent! Its Department of Communications Culture and Media Studies, for example, was deemed to have 70 per cent of its staff working at levels 4* and 3*. The shift in resource from applying the Roberts methodology was highlighted in *FST Journal*[1] by Professor Michael Arthur. He suggested that moving money away from the Russell and 94 Group institutions to others was a "long-term mistake".

A dilemma

The dilemma for HEFCE as it planned future funding was well illustrated by the views of the distinguished biologist and University of Manchester President, Dame Nancy Rothwell. She argued that while there was no objection to funding 'islands of excellence' in principle, such funding should not be at the expense of the top institutions: "We have to ask ourselves whether we want to be mediocre across the board or compete with the best in the world"[2].

So, thick or thin? Her article and others in *Times Higher Education* have provoked a lively and highly polarised debate. At one extreme, Professor David Colquhoun has suggested that post-1992 universities should abandon research altogether and become teaching-only institutions. Should individuals at such institutions be working at the top level in research, then they should move to 'research-intensive' universities. A similar proposal by Nobel Laureate Andre Geim (University of Manchester) was reported in *Physics World*[3].

Critical size?

Not surprisingly, representatives of the less research-intensive universities take a rather different view. They argue that the concept of critical size has been exaggerated and in this they find support from an unlikely source, a theoretical physics paper published in *EPL* (Euro Physics Letters)[4]. By using the methods of statistical physics and examining data from research assessment exercises, Kenna and Berche concluded that a small research group must, to maintain quality, achieve a *lower critical mass*: the optimum size turns out to be in the range 10-15 for physicists and earth scientists, but much less for social scientists and mathematicians. Above a certain *upper critical mass*, research quality does not significantly improve with size.

As the debate goes on, each grouping within the university sector has made its position clear. For example, the Director General of the Russell Group has declared that: "In the current economic conditions, it is particularly important to invest limited funds in the places where they will have the greatest impact. Our world-class, research-intensive universities have the excellence, critical mass and multi-disciplinary capacity to compete globally. It is important that the Government does not try to spread limited funds too thinly particularly in postgraduate funding."

By contrast the Million+ Group writes: "It is now clear that the ring-fencing of research means substantial cuts in real terms. It is also particularly disappointing that Ministers want to further concentrate research funding. This is highly unlikely to achieve the Government's objectives of promoting innovation or add to capacity to promote regional or national growth at a time when there are still major question-marks over economic recovery."

The 94 Group reaffirms its belief in the link between research and teaching by declaring that research-led teaching is central to the 1994 Group's mission and is the key to high levels of student experience and satisfaction.

Objectivity

Given the importance of deciding on the right amount of selectivity, particularly in times of financial stress, the debate requires more objective analysis and less narrowly-focussed special pleading. In this context the Adams and Gurney 2010 HEPI paper *Funding Selectivity*[5] deserves special consideration. By detailed citation analysis, Adams and Gurney conclude that the outstanding research achievements of the UK arise primarily from the work of a very small number of individuals in an even smaller number of institutions: "The majority of the research done in this country – throughout the sector, from the most exalted institutions to the least, and from those that have received the most research funds to the least – is very much more modest." They go on to assert that there is no case for a general and wider policy to concentrate funding based on historical performance.

When Lord May was President of the Royal Society, he often remarked that outstanding research was not done by universities, faculties or departments but by individuals. As an illustration of May's principle, consider the list of 'top' 100 chemists worldwide, produced by Thomas Reuters at the request of *THE*[6] on the basis of their citation performance. The UK has four individuals compared with 70 in the USA and seven in Germany. Of the four, one (Sir Richard Friend) is based in the Cavendish Physics Laboratory. As for the other three, Seddon and Holbrey are at Belfast and Champness is at Nottingham. Neither of these two institutions reaches the top 150 in terms of World University Rankings according to *THE* methodology, although both are in the Russell Group.

Finding the balance

The Foundation for Science and Technology itself does not have an opinion about the issues raised here: its role is to encourage informed debate. This does not, however, preclude your Editor from expressing a personal opinion. I have long believed that over-concentration of funding based on the perceived standing of an institution is not necessarily the most effective way of ensuring high quality research. Good people and good ideas have a habit of springing up in the most unlikely of places. The balance is clearly difficult to get right and, anyway, how would one define right? My feeling, however, is that to reduce funding for work deemed to be internationally recognised is a mistake and, at the very least, I would like to see the 9:3:1:0:0 ratio restored. ☐

References

1. *FST Journal* (2009) 20(2) page 6
2. *Times Higher Education* (2010) No 1965
3. *Physics World* (2010) 23(11) page 6
4. *Euro Physics Letters* (2010) 90, page 58002
5. Higher Education Policy Institute (2010) *Funding selectivity, concentration and excellence - how good is the UK's research?*
6. Times Higher Education (2011) No 1985 page 20

update

cont from page 2

National Space Strategy published

The Space Leadership Council has set out a series of actions to boost the UK space industry and achieve outcomes set out in the Government's Plan for Growth. The National Space Technology Strategy for the UK details priority research and technology areas to help the UK space sector grow, including telecommunications and access to space. This will support the National Space Technology Programme announced in the Growth Review and help UK businesses make the most of foreign markets.

Sir Keith O'Nions, Chairman of the National Space Technology Strategy Group who produced the strategy, said: "We have always said that this is a 'living' strategy and we will update this on a regular basis. In the meantime, I look forward to this strategy being nationally owned and implemented because doing so is going to be critical to achieving the growth in the sector to which we all aspire."

The National Space Technology Strategy is the result of a six-month process, working with all areas of the space sector and taking a range of views and expertise onboard. A series of 'roadmaps' were then produced, giving industry the clear, actionable guidance needed to drive innovation and increase market share in areas such as telecommunications, sensing, exploration and access to space.
https://ktn.innovateuk.org/web/national-space-technology-strategy

The Government's funding of science and research involved some hard decisions. How are these likely to impact researchers in practice? The issue was addressed at a meeting of the Foundation for Science and Technology on 2 February 2011.

Allocating science and research funding

Adrian Smith

The funding allocations announced last December derive from the extensive consultation on which the Comprehensive Spending Review decisions taken by the Chancellor of the Exchequer were based. That process has helped to ensure that the decisions have been widely welcomed by the science community.

In the area of Higher Education and Research, the Department for Business, Innovation and Skills (BIS) works with the HE Funding Councils, the Research Councils, and National Academies as well as a number of innovation bodies. The BIS mission is to produce and sustain a strong and competitive economy. Central to achieving this is the work of universities and strong links between universities, industry and public services as well as the effort to find ways to harness this country's superb research base to support innovation and technology development.

Remaining competitive

As a nation, we must respond to international competition by maintaining appropriate spending on science and research. Where do we stand against our competitors? If we take citations as a measure of academic excellence, the UK research base has the highest productivity in the G8 of in terms of citations per million dollars, with 1.6 citations per million dollars of public spending on R&D, compared to 1.1 achieved by Canada and less than 1 for the rest.

Can the Government justify spending taxpayers' money on the science and research budget? Yes, but we must engage with the public and win their support to make the case effectively. We need to stress the broad economic benefits that follow from a strong science base. These include the generation of new business – we are second only to the USA in creating new companies from the research base. Two companies from Cambridge, Autonomy and Arm Holdings, are now in the FTSE 100.

Investment in science and research also improves the performance of existing business as well as supplying highly skilled people to the labour market. BIS acts as custodian of the research base for all Government departments, thereby improving public policy and public services. And the UK research base is a magnet for R&D investment from global business.

Sir Adrian Smith FRS is Director General, Knowledge and Innovation at the Department for Business, Innovation and Skills (BIS). Previously he was Principal of Queen Mary, University of London and Professor of Statistics, Head of Department of Mathematics, as well as a Member of the Management and Planning Group and Company Director of ICON (Imperial Consultancy) at Imperial College.

To those ends, there has been increasing cooperation between businesses and the universities in recent years. The Government has maintained the Higher Education Innovation Fund (HEIF) element of university funding to further enhance universities' capacity to work with business. Last year universities in this country secured £3 billion of income from external sources.

In addition to the Research Councils, we now have a national innovation agency, the Technology Strategy Board (TSB), focused on the development of new technology-based products and services for future markets.

Excellence in research

What is certain is that funding must focus on excellence. In hard times we should not switch off the tap for young researchers or the next generation of researchers. We need to ensure that we have the national capability to support other Departments across Government, including inputs into health, the environment and energy as well as policy on climate change. This has to be underpinned, in many areas, by access to a large-scale research infrastructure. We also have to be able to cope with national challenges, such as foot and mouth disease, flooding and Icelandic volcanoes.

The results of the consultation and decision making process can be found in the document *The allocation of Science and Research Funding 2011/12 to 2014/15: Investing in world-class science and research*, available from the BIS website[1].

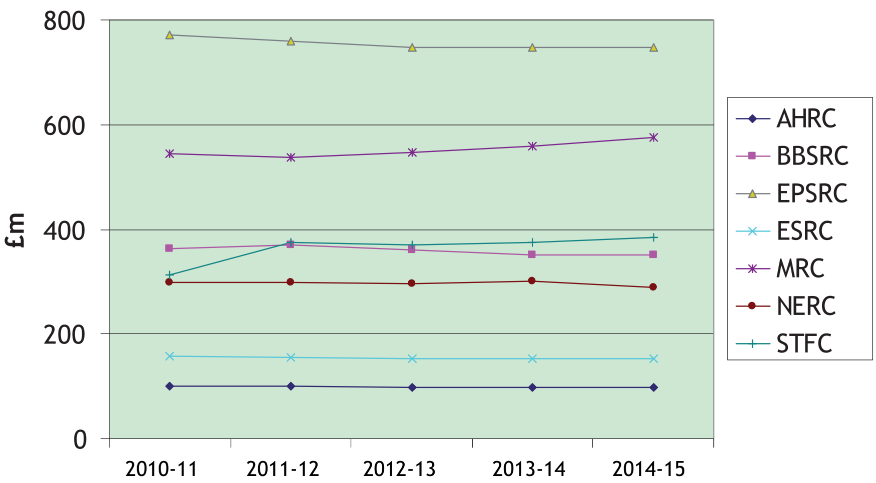


Figure 1. Allocation of funds to the Research Councils, from 2011 to 2015. Source: BIS; Arts and Humanities Research Council; Biotechnology and Biological Sciences Research Council; Engineering and Physical Sciences Research Council; Economic and Social Research Council; Medical Research Council; Natural Environment Research Council; Science and Technology Facilities Council.

Council	Baseline 2010-11 £'000	2011-12 £'000	2012-13 £'000	2013-14 £'000	2014-15 £'000	Total £'000	FinalYear to Baseline
Research Councils	393,438	239,821	199,393	181,430	180,967	801,611	46.00%
AHRC	3,150	0	0	0	0	0	0.00%
BBSRC	66,480	38,000	29,700	29,700	29,700	127,100	44.68%
EPSRC	49,261	31,000	35,000	25,000	25,000	116,000	50.75%
ESRC	20,600	18,700	13,700	12,700	12,700	57,800	61.65%
MRC	134,517	33,000	29,000	31,000	31,000	124,000	23.05%
NERC	34,183	32,200	17,800	17,800	17,800	85,600	52.07%
STFC- Core Programme		19,630	21,981	14,237	14,169	70,017	
STFC- Cross-Council Facilities		21,070	21,919	22,463	22,931	88,383	
STFC-International Subscriptions	85,247	46,221	30,293	28,530	27,667	132,711	75.98%
Large Facilities Capital Fund	103,380	115,279	61,307	47,769	128,132	352,487	123.94%
UK Space Agency	19,000	19,000	19,000	19,000	19,000	76,000	100.00%
HEI Capital HEFCE	166,952	75,170	90,970	90,160	101,500	357,800	60.80%
HEI Research Capital England	158,420	53,199	64,377	63,810	71,831	253,217	45.34%
HEI Research Capital Scotland	23,622	8,620	10,431	10,339	11,639	41,029	49.27%
HEI Research Capital Wales	6,031	2,113	2,557	2,535	2,854	10,059	47.32%
HEI Research Capital N. Ireland	1,778	798	965	957	1,077	3,797	60.57%
TOTAL	872,621	514,000	449,000	416,000	517,000	1,896,000	59.25%

Table 1. Capital allocations. Source: BIS.

The outcome of the spending review is cash protection for the seven Research Councils across the four-year period, with £4.6 billion per annum for science and research programmes in each year to 2014-15 (Figure 1). There is no change from 2010-11 in cash terms, and the spending is ring-fenced. Importantly, and for the first time, the complete package, both of the English quality-related (QR) funding and the UK Research Council funding, is within the ring-fence. In the past, that was true of the Research Council stream but not of QR.

Capital spending is reduced by approximately 40 per cent, however, which is in line with cuts occurring across government (Table 1). That is not good news, but there was a lot of capital awarded in the last spending review, which enabled us to catch up and take remedial action for previous underinvestment.

Additional funding

In the Budget in March 2011, an additional £100 million was announced for science capital projects. This investment will develop infrastructure at national research campuses in Daresbury, Norwich and Cambridge as well as the development of the International Space Innovation Centre at Harwell. This is vital investment in our research base, particularly in life sciences and space industries, which is critical for delivering economic growth.

During 2011 there will also be announcements of funding for projects arising from the 2010 Large Facilities Roadmap. The Research Councils collectively identify the road map for major facilities and prioritise them. The resulting priorities are then agreed by Ministers and, as capital becomes available, there will be announcements of new initiatives within these areas. Since the Spending Review, the Government has announced funding for three projects, including the Birth Cohort Study.

The Science Budget allocations will provide funding for the new UK Space Agency, to put it on a firm footing in order to develop space infrastructure, products, services and new research. In addition, these allocations will support the development of rigorous, quantitative methods in the humanities and social sciences through work with the British Academy and there will be a new cross-Council programme on global food security.

Support

With a budget in the order of £300 million per annum, the Technology Strategy Board will provide support worth over £1 billion for business-led R&D over the Spending Review period. This funding includes over £200 million over the four years, to establish an elite network of Technology and Innovation Centres (TICs) and to deliver a national single company Grant-for-R&D scheme. The areas for the first three TICs have been specified as high Value Manufacturing, Cell Therapy and Offshore Renewable Energy.

This adds up to a good result for science and research, albeit with some remaining challenges, at a time of immense pressure on public spending. ☐

1. www.bis.gov.uk/assets/biscore/science/docs/a/10-1356-allocation-of-science-and-research-funding-2011-2015.pdf

DISCUSSION

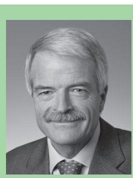
Maximising benefits

Effective collaboration between the different parts of the scientific community and a focus on centres of excellence are vital to ensure that maximum benefit can be derived from public investment in the science base. This may be difficult to achieve and it is not clear whether the Research Excellence Framework (REF) process contains adequate incentives to foster the desired focus on collaboration.

New funding realities mean changing priorities

Malcolm Grant

We have enjoyed a decade of ring-fenced science investment, reflected in the introduction of full economic cost recovery on research council grants, by charities, by quality-related (QR) research funding and reinforced by the introduction, in 2006, of a new system of tuition fees. Before these innovations, universities (and particularly our research-intensive universities) were running themselves into the ground. They were competing to sustain a research venture for which they were inadequately resourced and for which they could neither furnish the infrastructure nor invest properly for the future.



Professor Malcolm Grant CBE is Principal and Provost of University College London. Born and educated in New Zealand, he is an environmental lawyer. He is a member of the Higher Education Funding Council for England, the Economic and Social Science Research Council and the Hong Kong University Grants Committee. He is also a Governor of the London Business School and the Ditchley Foundation.

It has been apparent for several years that the party was coming to an end. Most universities have had to make tough internal savings and have been recruiting strongly internationally. Some leading institutions already derive more fee income from international students than from the Higher Education Funding Council for England (HEFCE) and that will soon become the norm.

There has also been a significant concentration in research funding within the scientific research-orientated institutions. The major five institutions in the UK account for about 28 per cent of QR funding as a consequence of their performance in the last Research Assessment Exercise (RAE).

The implications for science

The headline news about science research is good, but there are a number of caveats. First, nobody should believe that it is business as usual. Universities will be completely transformed, not just by this settlement but by the new tuition fees regime for UK and EU undergraduate students.

There are a number of reductions that will take effect over the coming years, starting with the flat-cash science settlement, in effect a 10 per cent reduction in science funding to our institutions. Higher education and research institution budgets will also have to absorb the impact of policy changes in other areas such as the NHS, as well as the increase in VAT and National Insurance. At University College London, this means a potential budget cut of between £20-25 million on an £800 million annual budget,

Then there is the issue of tuition fees. We were expecting a dramatic reduction in public expenditure whichever party was to form the incoming Government. The three choices open to the Department for Business Innovation and Skills (BIS) were to cut student finance, to cut research or to cut student numbers. The student number cut is politically unacceptable, the research budget was hotly defended, so it was student finance that was given particular focus in Lord Browne's report[1].

The Browne report proposed a market-oriented model for funding students, where funding followed the student and in which the student had a choice of institution. The Coalition Government proposals did not follow the economic model upon which the report's recommendations were based and this could well result in unexpected and undesirable disincentives to investment in teaching and research.

Universities are permitted to charge fees of £6,000 to £9,000 per year, subject to review by the Office of Fair Access. In the current state of financial uncertainty, most universities have been drawn to the upper end of that range.

The uncertainties derive from the withdrawal of Government funding for the arts, humanities and social sciences, and reduced funding of the same amount per capita for clinical and laboratory-based science. Further uncertainty stems from the retention of student number quotas. There will be no flow of students between institutions, so no true market.

The policy changes on immigration are of particular concern. This country has had remarkable success in attracting outstanding international staff and students to study and work in our universities. Yet the proposed new immigration policies make it clear that students are not welcome, that we need to reduce abuses and that we need to restrict work opportunities for students educated here. This puts at risk an enormously valuable and strategically developed operation that does not just bring funds into the university system but creates a legacy of valuable interactions with generations of students around the world.

There is also uncertainty about the future of charity funding. Charitable endowments held up well during the recession but growth will not continue. Institutions with large-scale medical operations are heavily dependent on charitable funding for outstanding science. The Wellcome Trust's introduction of investigator awards, as opposed to funding programmes and projects, is another source of uncertainty. Yet another is the volatility within the NHS, a critically important player in medical education and research.

Managing the research budget

The Research Councils are also under pressure. They have a valuable flat-cash settlement, but are being urged to reduce staffing levels. This means that the way they manage the research budget will have to change. We are already seeing –– and rightly so –– fewer small grant programmes and a greater concentration on large grants. The net effect may be to transfer responsibility for demand management and concern for interdisciplinary research centres from the Research Councils to the universities themselves.

The Higher Education Innovation Fund (HEIF) has been a success, allowing universities to hire people and promote enterprise, and also to get involved directly in commercialisation. It is good news that the HEIF has now been renewed, but the latest formula leaves 25 of the top-performing institutions capped, rather than allowing a greater flow of investment into the highest performers in the country.

DISCUSSION

Investment

There is concern about the cut in capital funding and the impact on that for UK competitiveness. Substantial investment has been made in the past decade, however, and some cuts are inevitable. There is a need to encourage the exploitation of scientific advances in the form of new products and manufacturing processes. The Technology Strategy Board (TSB) can make an important contribution in this area, but public sector research establishments could also help.

There is a widely held view that the funding settlement has seriously harmed the arts, humanities and social sciences. I cannot conceive of a university worthy of that name that does not invest heavily in these areas. They are an integral part of what we do. In many ways this is the decade of the social sciences: everything we discover, invent and apply through science has a profound social science implication. For example the recent announcement that we are likely to revisit the genetically manipulated (GM) crops debate is not so much an argument about science, but about social science, public perceptions and public views. Clearly, though, some funding has been lost and future funding is more dependent upon student choice.

A further issue in the funding of the arts, humanities and social sciences is that one third of QR funding is allocated across these areas. This is their life blood: it may be a small proportion of what they need but it arrives in the university as a block grant — it is allocated direct to the university, not to researchers or heads of department. Universities have the responsibility for the internal allocation of those resources to support subjects that they value: if that requires reallocation of funds internally, that is the university's responsibility. The universities themselves are best placed to know how to spend that money wisely, and Government should not take over that responsibility.

Not purely utilitarian

It remains vital, though, to avoid the impression (which is already starting to gain currency) that the value of a higher education in the future is to be measured only in utilitarian terms, by the value of income generated for the individual after they have graduated. I do worry about the Government's proposals to insist universities provide information for students telling them the median income of graduates of a particular course, five years after they finish. The test of an education has to be academic rigour and personal fulfilment — values that are not easily captured by simple measurements but nonetheless values that we should be striving to instil. Ambition must range well beyond short-term financial return.

The new settlement and the heavy dependence on tuition fees in future will have important consequences, and not just at undergraduate level. Not much has been said about the removal of public funding for postgraduate taught courses. For an institution like University College London that amounts to a further £9 million a year. Postgraduate taught education has risen sharply in popularity during the past decade. Many students wish to deepen or broaden their studies across a wider area; yet not only is the HEFCE grant towards postgraduate tuition due to disappear in stages, these students will not have access to the loan book. So we face the prospect of a generation coming through with repayable graduate contributions approaching £30,000 and no funding for postgraduate programmes.

Where is all this leading? More students will live at home and go to nearby universities. There will be a shift to quality — students will value universities able to give them a high quality degree and enhance their employability prospects. And as research funding starts to decline as a proportion of the total budget of the institution, universities will need to focus on world-class teaching.

This country has pushed competition as a way to drive research quality – pretty much as far as it reasonably can go. We have, however, tended to neglect collaboration. Yet there are lessons to be learned from the Francis Crick Institute now taking shape in St Pancras. This type of collaborative venture may become a model for a science community coming to terms with the new settlement. Our future in science research can no longer depend primarily on the competitive performance of individual institutions, but on a more sophisticated and enlightened approach to collaborative ventures. ☐

1. www.bis.gov.uk/assets/biscore/corporate/docs/s/10-1208-securing-sustainable-higher-education-browne-report.pdf

The future of the UK pharmaceuticals industry

Patrick Vallance

The future of the pharmaceutical industry is intimately linked with the health of the science base in the universities. Our industry is going through a period of major change that will leave it looking very different from the pharmaceutical model of the past.

The fundamental problem facing the industry is a failure to produce enough new medicines at affordable prices. It costs on average $1.6 billion to produce a new medicine and it takes on average 12 years. Across industry the number of new medicines making it through to market each year is no higher than it was 15 years ago.

The industry has responded in two ways. First, companies are looking outward, forming R&D partnerships with biotechnology companies and with academia. Second, companies are looking to invest in drug discovery where they can see the best chance of making a medicine. For example, in psychiatry we know so little about how the brain works that to pick a drug target is very tough. Animal models are poorly predictive in this area, early clinical studies do not predict the outcome, diagnosis is difficult, unwanted effects of drugs that work on the brain are often significant and the placebo response is high. Even when a drug is developed that works, it will fail half the time in large-scale registration studies. On the other hand, with a simpler monogenic disease, it is easier to be sure of the target, diagnosis is simpler and clinical trials more efficient. These types of consideration explain why there is much more activity in some areas than others, why companies are shifting resources from some disease areas and why there will be more focus on medicines for smaller indications.

Furthermore, the nature of what is considered a medicine in changing. The classical small-molecule white pill is no longer considered the default option. Antibody-based treatments are here to stay, technologies based on antisense, gene therapy and even cell-based therapies are now in the drug development pipelines. These technological changes mean a change in some of the skillsets required and the approaches needed from industry.

Such shifts have profound implications for the UK. The country has a strong presence in big pharma R&D, in the traditional model and in academic biomedical research: it is less well represented in biotech, though. To redress the balance specific measures are needed to encourage biotech start-up, growth and sustainability.

At GlaxoSmithKline, drug discovery activities are now about half internal and half external. The company has significant partnerships with UK academia as well as agreements with biotech companies across the world (these include some, but not many, in the UK).

We support the therapeutic clusters which enable access for clinical investigators to better characterised patient groups for specialist studies, and we plan to undertake a new venture with the Medical Research Council to open up our Clinical Imaging Centre at Hammersmith to a new model of public-private partnership. The company has also donated land at Stevenage to create a new model of science park, Stevenage Bioscience Catalyst. We see the UK science base as strong and believe that academia is increasingly willing to be true partners in some of these key areas. However, so is the rest of the world.

Key questions

There are four key questions we ask when making a new medicine:

- what target should we select?
- which molecule should we select as our medicine to tackle that target?
- how can we demonstrate early in the clinic that the promise of the new medicine holds up?
- how can we demonstrate the value of our medicine to patients and the healthcare system?

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In big pharma we are really good at some parts of this process and much less good at others. In turn, academia and biotech have huge strengths in some of the parts we are not so good at. Playing more clearly to strengths in each sector is going to be key.

To do this, it is vital to have a workforce that is highly skilled and well linked into academia. The UK universities train well and that needs to continue at undergraduate and postgraduate level with domestic and overseas students. However, I would like to see more flexibility of movement between academia and industry.

Basic science activity is essential — it is here that target identification and technology advances will emerge. This focus on basic science needs to be coupled with a willingness to translate into practical outcomes.

Medicines must be tested early in the clinic so as to understand their potential. This area of experimental medicine has been a traditional strength in the UK, bolstered by The Wellcome Trust, MRC and NHS R&D investment. This is the area where the UK could make a big impact.

The clinical trials infrastructure has improved but it is unlikely that there will be any particular advantage over other countries – and for global registration, global studies are required. However, there are two areas of potential advantage in the UK. One is that the NHS could choose to undertake a complete study of a new drug where the conventional market pull may be deemed weak — for example new antibiotics, or medicines for an area like premature labour. Another is that effectiveness trials based on electronic patient data are going to be important and the UK could be at the forefront of this. This will require not just infrastructure but also expertise in data-mining and signal detection.

Key importance

I welcome the protection of the UK biomedical science budget and believe it is of key importance to the pharmaceutical industry's activities. The Research Councils are proceeding in the right direction, interacting positively with our sector, and the MRC is working well with NHS R&D to support patient based research. I would like to see coordinated measures to stimulate the biotech environment as well as further use of the Research Excellence Framework (REF) – the new system for assessing the quality of research in UK higher education institutions – in order to reward collaboration with industry, risk taking (including spin-outs) and staff mobility.

Ensuring that we build on a critical mass of excellence is key and I believe that geographic clusters are important for creating the right environment for invention. In this respect, the concentration of top class research universities, the formation of the Francis Crick Institute, developments such as the Catalyst Science Park at Stevenage and the skilled pharmaceutical workforce in the South East, represent clear opportunities.

The UK science base is outstanding: others will find it hard to catch up and we have an opportunity to play to our strengths. We must not damage that fundamental strength in science: I believe that this message is clearly understood by Government and reflected in some of the ambitions in the spending review. Finally, the advances in biomedical science will translate into huge opportunities for health and wealth improvement and the opportunities for making new medicines have never been greater. ❐

DISCUSSION

An engine for growth

Science has failed to capture the public imagination in recent years. Science can be an engine of growth, so at a time when growth is much needed it should not be starved of funds. While the scientific community may be able to help the Government construct a strategy for growth, will this be perceived as just another lobby group asking for funds?

The implications for the UK of the incident at the Fukushima nuclear power station in Japan were debated at a meeting of the Foundation for Science and Technology on 18 May 2011. The meeting began with a minute's silence for the victims of the catastrophic earthquake and tsunami.

The importance of scientific advice in disaster response

John Beddington

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

The combination of events that led to the incident at the Fukushima nuclear power station was extraordinary – one of the largest earthquakes ever, sited almost perfectly off the coast of Eastern Japan to maximise the impact of the resultant tsunami on North Eastern Japan and the Fukushima nuclear plants.

When the earthquake occurred, the reactors automatically shut down. The fundamental design worked in so far as the reactors shut down and they were not operating when the earthquake struck. However, the tsunami was enormous – the barriers were in the order of 3-5m while the wave was 10-15m in height. The combination of earthquake and tsunami damaged the supply of offsite power and onsite backup systems which fatally undermined the ability to cool the residual radiation in the reactors.

The Prime Minister decided to convene a COBR disaster response group. The key question for the UK was whether to evacuate its citizens from North Eastern Japan, including Tokyo. I was asked to set up a Scientific Advisory Group in Emergencies (SAGE) to consider this question and the associated issue of whether to move our Tokyo embassy staff, as the French and German governments did. The advisory group attempted to determine a reasonable worst-case scenario: the worst that could happen given what was known of the situation there. The conclusions would guide the advice provided with regard to travel, food, water and so on.

The group included representatives of the British Geological Survey, the Cabinet Office and several excellent independent scientists – Professor Robin Grimes, Dame Sue Ion and Professor Richard Wakeford. In addition, we were able to draw on the knowledge of experts outside central Government; for example we had colleagues from the National Nuclear Laboratory and the Chief UK Nuclear Inspector, Dr Mike Weightman, and his team were also involved.

We knew what was in the reactors from IAEA and other international sources, which we used as the basis of our analysis. There were, essentially, three reactors that were in operation and that had not been cooled properly. In addition, there was cooling issues with the ponds that kept spent fuel, and these cooling ponds were located close to the reactors.

Communicating important messages

The first important message to communicate was that this was not Chernobyl, which involved an extended release due to fires in the graphite cooling rods that lofted radioactive contamination thousands of feet in to the air. A worst case in Fukushima would be a reactor meltdown leading to the reaction of radioactive material with the floor of the reactor containment vessel, and a subsequent release of hydrogen gas causing an explosion which would put up radioactive material into the atmosphere to a height of about 500m. For a single reactor, this would last a few hours. The worst case would be for the wind to take this material in the direction of the major centres of population such as Tokyo.

Now, a reasonable worst case might be one reactor and one pond going up, and indeed those were the first calculations. However, because of the siting of the reactors and the closeness of the reactors to each other there would be a potential for a cascade effect: if one reactor had exploded and emitted a vast amount of radioactive material, the ability of the authorities to keep cooling the other reactors or the fuel ponds would be significantly diminished, if not impossible.

So the 'enhanced worst case' looked at all three cores of the reactor melting down and producing an explosion with the six cooling ponds also releasing nuclear material.

However, up-to-date weather information enabled us to advise for example: 'Don't worry, whatever happens the prevailing wind is out to sea'. We ran calculations, every three or four hours, based on our worst case scenario and the winds forecast over that period, which allowed us to estimate dosages at key locations. It became apparent from early calculations that, even in the enhanced worst case scenario, the radiation effects on human health in Tokyo would be negligible even assuming a constant wind direction towards the city.

That was a difficult message to convey

DISCUSSION

Effective communication

Crucial to reassuring the public after a disaster is a clear recognition of the problems by Government and the appointment of effective communicators. The public does not trust politicians or anyone perceived to have a commercial interest. So communication must be led by independent experts, who must know how to put their views over. It is the independence and scientific authority with which they speak, rather than eloquence, which will meet the public's concerns.

because the media storyline was: 'This is a disaster, why aren't we evacuating our citizens?' We sent our calculations to colleagues both in France and America, using Mike Weightman's network and the Network of Chief Scientists. We understand that the calculations we made were the same as the Americans and the French, yet France moved its embassy staff while the USA and the UK did not.

With help from the Health Protection Agency and the Department of Health we set up teleconferences, via the UK Embassy in Tokyo, to communicate to British people in Tokyo and North Eastern Japan. We were able to answer the concerns that people posed, explaining our understanding of the situation and responding to 'What if?' questions.

Our advice was unequivocal: we did not need to evacuate the Embassy, we did not need people to abandon Japan, although we did think there should be a precautionary zone around Fukushima somewhat larger than the one established by the Japanese. One of the difficulties in this kind of exercise is keeping hazards in perspective, so for example we made the point that leaving Tokyo and flying to New York would result in exposure to more radiation than staying put.

Scientific and engineering advice

There has been a degree of over-reaction and panic – at policy level as well. This underlines the vital need to take scientific and engineering advice rather than making policy 'on the hoof'. There was an EU decision to tighten the standards on imported Japanese goods, for example, but the current standards have been worked out by expert advisory committees. It was profoundly unscientific and to be regretted.

An obvious point, but one that bears repeating, is that the UK is not in an earthquake zone. However, there are risks – flooding is one – which should prompt reflection about robust back-up systems and siting (should nuclear reactors be sited close together or not, for example).

The nuclear disaster at Fukushima has enormous personal consequences, both for people who work at the plant and those who live nearby. There is no doubt that many have acted with great courage. Closer to home, I think the way that Government has acted and the way we have been able to communicate the advice that we have developed is reassuring proof that the Government is listening to, and reacting upon, clear and informed scientific advice. ❑

Public attitudes to nuclear power

Nick Pidgeon

Why are public attitudes important – why not just ignore them? Well, evidence from a range of studies over a number of years shows that attitudes can influence the development of a technology – take GM foods or renewable energy for example. Go back into the history of nuclear industry to a time just after Chernobyl and almost 80 per cent of those polled in Europe and North America were hostile to nuclear energy.

It should also be noted that attitudes to risk go beyond the accepted *engineering* concepts of probability and consequences. There are political and cultural factors which shape attitudes, something called 'social amplification of risk'. Trust – or the lack of it – is absolutely essential here. Over many years there has been a history of distrust of the nuclear industry, for various reasons, and this has in turn shaped the views people have about the risks of the technology.

Research also suggests that if a risk is imposed, is involuntary, is unfamiliar, or seen as irreversible, then people get an 'uneasy feeling'; an affective response to some risk issues which makes them less acceptable all other things being equal. Polling by the Nuclear Industries Association – the most longstanding annual UK tracking poll – shows a gradual increase in support for nuclear energy and a decline in opposition since about 2001. That result is broadly consistent with other evidence.

Professor Nick Pidgeon is Professor of Applied Psychology at the School of Psychology, Cardiff University. He directs the interdisciplinary Understanding Risk Research Group which looks at how public attitudes, trust and institutional responses drive environmental and technological risk controversies. From October 2008 he took up a three year Economic and Social Research Council Professorial Climate Leader Fellowship investigating public risk perception, climate change and public engagement.

Detailed attitudes of the public

Tracking polls are fine as far as they go but the number of questions involved is typically quite limited. Research at Cardiff, funded by the Economic and Social Research Council, looked at a broader range of questions and placed nuclear energy in relation to the policy debates on climate change and energy security. Two major surveys in 2005[1] and 2010[2] (of more than 1,500 adults in each case) included a range of identical items. These are both available on the Cardiff website[3].

In these two studies we found that nuclear energy is still not liked in comparison with other energy technologies and particularly renewable energy. Why people have strong positive beliefs about renewable energy, is a separate matter, but nuclear was least favoured alongside oil and coal, while gas and biomass were intermediate. This ranking is very important for the whole long-term energy debate which will encounter difficulties if it does not take at least some account of public preferences.

However, far fewer were 'very concerned' about nuclear energy in 2010 compared to 2005, and there was perceived to be less risk and more benefit than in 2005.

Now there is much higher support if nuclear is considered in relation to issues like energy security and climate change. A statement like 'We need nuclear power because renewable energy is not able to meet our electricity needs' achieves a favourable response from more than 50 per cent and there is a similar response in relation to climate change. Yet if the same people are asked whether promoting renewable energy resources such as solar and wind is a better way of tackling climate change, support for that approach is even stronger – around 70 per cent.

I believe that opposition to nuclear power has fallen for two main reasons. First, the energy security and climate messages have over the last 10 years been communicated through policy, by industry and by some environmentalists: this has impacted public beliefs. In addition, the lack of visible accidents has played a part, so it will be interesting to see what happens now. Overall, it would be correct to say that there has been a reluctant acceptance of nuclear but that, given the choice, the public would remain more supportive of renewables.

The local dimension

Things are never as straightforward at the local level. Each existing nuclear site is subtly different and the communities there are different from each other too. Support tends to be higher at existing sites but, again, it is a complex picture. Community benefits, familiarity over many years – and trust – all matter at a very local level while whatever people say overtly, anxiety still remains just below the surface.

We conducted a major project for the Economic and Social Research Council looking at the situation around three existing sites – Bradwell, Oldbury and Hinkley[4]. All of the interviews and surveys were carried out within eight miles of each site. People were familiar with their local site, which in all cases had been there for at least 40 years. Each had been operating seemingly without major problems; in fact, for many we interviewed, the local plant was just a part of the landscape. Interestingly, many respondents felt the operators could be trusted to deal with safety because they lived there and would not do anything to put themselves and the community at risk of harm. So there was a social connection there that came from living in the place and having local members of plant staff living there too.

Concerns remained though. Nuclear energy is not like other engineering technologies – it has associations with atomic weapons and with politics, for example. The Fukushima events will have raised anxiety about the management of such local plants, even though this was an overseas event caused primarily by a natural disaster.

Early polls suggest that at the national level support for nuclear energy has dropped following the accident, but not as much as might have been expected. Perhaps this is because Japan is geographically distant, the cause was primarily a natural event and, therefore, nobody was to blame, unlike at Chernobyl or Three Mile Island. On the other hand, perhaps climate change and energy security are actually very powerful influences on public attitudes.

Whatever the case may be, longer-term studies are needed to judge the real impacts of the Fukushima events. However, the dialogue that the industry, Government and other stakeholders will need to have with the communities where new plants are planned in Britain will not be as straightforward as it might have been before. Openness and transparency, along with responsible risk management, will be prerequisites to rebuilding trust on this issue. ☐

1. Poortinga W, Pidgeon N and Lorenzoni I (2005) *Public Perceptions of Nuclear Power, Climate Change and Energy Options in Britain: Summary Findings of a Survey Conducted during October and November 2005.* Technical Report (Understanding Risk Working Paper 06-02). Cardiff: School of Psychology.
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3. **www.understanding-risk.org**
4. Parkhill K A, Pidgeon N F, Henwood K L, Simmons P and Venables D (2010) From the familiar to the extraordinary: local residents' perceptions of risk when living with nuclear power in the UK. *Trans of the Inst of British Geog*, NS 35, 39-58.

The design of nuclear power stations

Laurence Williams

Nuclear power stations are designed to withstand challenges from external events including earthquakes and flooding but the Japanese tsunami which hit the plant at Fukushima was about 14m and above the plant's tsunami protection wall. When the wave hit the turbine building it splashed up to 46m, a scale of violence that we find difficult to contemplate.

The Fukushima installation itself is a fairly old power station by light water reactor standards. Unit 1 was commissioned in 1971. It is a first generation boiling water reactor. The key components are the large pressure vessel in the centre, which operates at 75–80 bars, about half that of a pressurised water reactor like the one in the UK at Sizewell. The containment building – the 'dry well' – is also quite unusual by UK standards. At the bottom is the 'wet well', or 'torus', required if there is a loss of turbine and the steam has to be dumped. When the reactor has been shut down, the steam is injected into this water which eventually condenses it and then emergency cooling systems remove the heat. The reactor design is also unusual in that it has large water filled ponds for spent fuel removal and storage situated at a high elevation within the reactor building. In the Sizewell B reactor the spent fuel ponds are at ground level.

The course of events

At about 2.45pm on 11 March, a magnitude 9 earthquake, one of the largest in Japanese history, hit the nuclear plant at Fukushima. When the incident happened, everything initially functioned as designed. The three operating reactors were automatically shut down – the steam isolation valves kicked in, the diesel generators came on, emergency core cooling systems were working and the plant remained safe and in a stable condition. However, about an hour later, a massive tsunami hit the plant. This took out the diesel generators (as well as the tanks containing the oil for those generators), all the essential service-water buildings and the ability to cool the reactors. The control rooms were blacked out so the operators were faced with a complete failure of the emergency systems and very little instrumentation to tell them what was happening.

As has been recently reported by the plant operator TEPCO, between four and five hours after the tsunami hit the site, the water level in Reactor 1 dropped below the level of the fuel rods. The fuel rods became overheated and these began to melt (uranium oxide melts at about 2,800°C). Some 14 hours later, in the early morning, the operators were reporting very high temperatures and decided to inject water. It would appear that by about one hour after that the fuel rods had melted and the fuel had slumped at the bottom of the pressure vessel. The latest news suggests that there could be small holes in the bottom of the pressure vessels through which molten fuel is leaking. This did not happen at Three Mile Island and this may be due to the fact that pressure vessel at Fukushima is not as thick or be a result of the penetrations at the bottom of the pressure vessel that are used to insert the control and shutdown rods.

The loss of cooling water in the reactor core caused the fuel to overheat and react with the steam to produce hydrogen; this led to the build up of pressure in the pressure vessel. As a consequence the pressure release valves opened, the steam was injected into the wet well where it should have condensed. However, as there was no emergency cooling capability in the wet well, the water became saturated with the steam, volatile fission products and hydrogen escaping into the dry well above. Eventually the pressure there started to increase. To lower this, the operators vented the dry well, possibly not realising the extent of hydrogen build-up. This then leaked into the rest of the building and blew the top off Reactor 1.

There were early reports of steam emanating from the spent fuel ponds, indicating that they might be boiling dry. The concern was that if the water in the spent fuel ponds was leaking the levels could drop to the extent that the fuel could be exposed. This would result in high gamma radiation levels and the possibility of fuel melting. As the fuel ponds are outside the containment structure, radioactive fission products would be released directly to the atmosphere. There was little information on the state of the fuel ponds in reactors 1, 2, and 3. In the case of reactor 4, there was no fuel in the reactor core as it was under maintenance but all the fuel from the reactor was in the spent fuel pond.

The initial assumption was that the explosion in the Reactor 4 building was a result of the hydrogen produced by the reaction between the zirconium cladding and the water in the fuel ponds. More recent information from Japan suggests that was not the case. There was no significant damage to fuel in Unit 4. In fact, the explosion that ripped apart Unit 4 was caused by hydrogen produced in Unit 3, entering via connecting pipe work.

Design

The incident has highlighted design issues in regard to external hazards (including seismic events, tsunamis and flooding) as well as the loss of offsite power. It has also highlighted problems about the robustness of the site infrastructure, especially in relation to the emergency core cooling systems and in particular the back-up systems. The operators ran out of water quite early in the response and for a short

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time were even unable to pump seawater.

Severe accident management systems were developed after the Three Mile Island accident to cover situations which have gone beyond the original design basis assumptions. These enable the operators to mitigate the consequences of these accidents and , to help manage long-term action. This latest incident has highlighted the importance of emergency operating instructions and operator training in order to deal with very low-probability but high-consequence events.

In the UK there are annual emergency exercises at our nuclear installations to practise the response to plant malfunctions but these do not often cover severe accident scenarios. Equally, offsite exercises to test the readiness of the Government system and the emergency services do take place at regular intervals but again the exercise scenarios do not necessarily cover severe accidents.

In the case of performance standards, early UK plants were not designed specifically with seismic loading in mind although they were very robustly engineered. All plants since the late 1970s were designed to meet seismic response criteria set out in the Nuclear Installations Inspectorate's safety assessment principles (SAPs) which were published in 1979. These required designers to include a safe shutdown capability in the case of earthquake and take into account the most severe challenges relative to the location. These early SAPs gave the designers a clear guide on the range of external hazards that the designers needed to address, including earthquakes, flooding, extreme temperatures and extreme winds.

The latest Advanced Gas-cooled Reactors (AGRs) at Torness and Heysham, as well as the Sizewell B class of Pressurised Water Reactors (PWRs) – there were going to be five PWRs built to the same design – were designed to the most severe seismic loading so they could be built in any location. The Thermal Oxide Reprocessing Plant (THORP) at Sellafield was designed and built to meet these standards and all subsequent plants have been designed against a one-in-10,000 year event. The Nuclear Inspectorate also required additional criterion to be met. It was not sufficient to design a facility where the safety-related plant and equipment would accommodate an earthquake with a ground acceleration of 0.25g; designers were required to make sure there was no catastrophic failure at a 40 per cent more severe event, i.e. 0.35g. The design also had to withstand a 1-in-10,000 risk of flooding.

At an international level, nuclear safety standards are set by the International Atomic Energy Agency and these include those related to external hazards. The Nuclear Installations Inspectorate reviewed its SAPs between 2004-6 and they were aligned to the IAEA standards. The new versions are not very different from the 1979 documents.

Regulation

Regulation is an important part of the system that ensures the protection of the public. The regulatory system in the UK has an impact on the design and operation of plants to meet the threat posed by external hazards. In the UK every nuclear facility (that has not been exemption by Government) has to have a nuclear site licence. The standard licence has some 36 conditions attached to it and within these there is a whole range of requirements including those for safety cases covering the design, commissioning, construction, operation and decommissioning of the facility.

In addition, the Licence Conditions require periodic safety reviews (PSR) to be carried out every 10 years. These PSRs require the operators to review the safety of their facility against modern standards with any plant improvements being based upon reducing the risk 'as low as is reasonably practicable'.

Fukushima is an extremely serious event. There has been about one-tenth of the radioactive release of Chernobyl. Most of that has been into the sea rather than the air. In Reactor 1, and probably in Reactors 2 and 3, the core has slumped and the fuel is sitting on the bottom of the reactor pressure vessel. In at least one of those there has been a burn-through and leakage. Given that the current situations in the spent fuel ponds is still unclear, it will still take some time to completely resolve the incident. ❑

The implications for the UK

Mike Weightman

The interim report published by the Office for Nuclear Regulation of the Health & Safety Executive includes 10 conclusions and 26 recommendations[1]. The report may be interim, but the recommendations are firm. While more information may become apparent and we gain greater understanding, it is important to draw some conclusions at this point in time and make some recommendations.

One conclusion from all this work is that there is no need to curtail present operations at nuclear plants in the UK. There are several reasons behind this. First, the hazards directly involved in this incident – a Level 9 earthquake and the associated 14m high tsunami – are not credible risks in the UK: we are a thousand miles away from a fault line. We have, though, ensured that UK plants are protected against a very extreme seismic hazard, based on hazards of one-in-10,000 years, and with no 'cliff-edge' effects beyond that of up to around one-in-100,000 years.

We have also reassessed, with our colleagues in the Environment Agency and others, the existing information on the tsunami hazard for the UK and the likelihood of extreme flooding in the UK. For flooding, all UK power plants meet the 1-in-10,000 years criteria.

UK reactors are generally of a different design from Japanese ones, although this country does have a pressurised water reactor at Sizewell B which contains some of the most advanced features and containment structures. That reactor has around half the zirconium in the core that other PWR reactors have; this means the total amount of hydrogen that would be generated from high temperatures reactions is lower and the rate of reaction is lower.

The UK fleet, though, is largely composed of gas-cooled reactors. These use carbon dioxide as the coolant so there is no phase-change with increased temperature, the heat transfer characteristics do not change dramatically at any point and there is no interaction with the cladding of the fuel that could lead to hydrogen generation – which was an issue at Fukushima.

Dr Mike Weightman FREng is HM Chief Inspector of Nuclear Installations and Executive Head of the newly created Office for Nuclear Regulation (ONR), an Agency of Health & Safety Executive. He is responsible for securing the nuclear safety and security of the civilian nuclear industry including nuclear power reactors and nuclear chemical sites, such as Sellafield and nuclear research sites. He also has responsibility for ensuring the safety of the defence nuclear industry, including the refuelling of nuclear submarines and the Atomic Weapons Establishments at Aldermaston, Burghfield, etc.

The power density is a great deal lower in gas-cooled reactors – the density is about one-fortieth of that in a light water reactor as the power is spread over a larger mass. The thermal mass of the core is also far greater which means in reality that there is a longer time in which to address issues in the case of coolant loss.

Three days after the incident at the Fukushima plant in Japan, all UK operators were asked to provide assurances to the ONR that they had checked all the safety systems for flooding, for electrical supply, coolant supply and for seismic protection. That review was completed within a week and the Office for Nuclear Regulation has also made site checks. Not only did the boards of the operating companies convene special meetings over the issue, they even agreed to share their minutes with the regulator – an example of openness and transparency based on trust and confidence, as well as an indicator of the robustness and independence of the regulatory process.

Lessons to be learnt

The report looks at looks as the lessons to be learnt from Japan. The layout of plants, in particular the siting of essential nuclear safety equipment, is vitally important as are the emergency response arrangements, both on- and off-site. Disruption to the infrastructure lasted not days, but over a week. Are arrangements in the UK robust enough to ensure a site stays safe in those circumstances? How is it to be re-supplied with goods, services and carbon dioxide? How is the electricity supply to be reconnected? How robust would the National Grid be in such circumstances? Those are questions posed in the report and industry needs to respond.

The environment agencies have carried out detailed assessments of existing flooding risks in the UK. However, climate change is upon us and while it is not going to happen overnight industry must keep an eye on that in its periodic safety reviews.

The recommendations of the report cover four areas:

- international: information from any country where an incident occurs should come from an authoritative source and be distributed widely. In this way, other countries can make decisions about the well-being of their own citizens there, make their own independent analysis and determine how best to fulfil their prime duty as Governments to protect their nationals at home or abroad;
- national: approaches to emergency planning. This will include learning from the Japanese experience, in particular the way they were able, despite everything, including massive damage and disruption from the direct impact of the earthquake and Tsunami, to effect good evacuation over a wide area. How did they do that? Can we learn those things?
- regulation: a prime objective for a nuclear regulatory body is independence, openness and transparency. Through this we earn trust and confidence, from what we do and who we are. We have to accelerate our efforts in that area;
- industry learning: this is the most extensive area. Despite high standards, the industry must strive to improve through learning from what happened as part of a continuous improvement culture – the foundation stone of sustained high standards of nuclear safety. ☐

1. www.hse.gov.uk/nuclear/fukushima/interim-report.pdf

A meeting of the Foundation for Science and Technology held at the Royal Society of Edinburgh on 20 October focussed on the opportunities for Scotland from the digital revolution.

Can Scotland grasp the opportunities?

Michael Fourman

Before outlining the conclusions and recommendations of the *Digital Scotland* report, I want to draw attention to a report from the Boston Consulting Group concerning the way the internet is transforming the UK economy. *The Connected Kingdom* report finds that, compared with other developed nations, the UK has high levels of internet activity; however, this strength masks significant regional differences. London and the South East are doing well. Scotland, Wales and Northern Ireland are not. It also shows, however, that small- and medium-sized enterprises (SMEs) in Scotland come second for connectivity after London. So in reality Scotland is switched on, where it has connectivity.

By being connected to the internet, businesses can undertake geographic expansion without the need for a bricks-and-mortar presence. They can enjoy profitable sales of 'long-tail' products to small subsets of consumers. There is improved information exchange across supply chains which increases efficiency and productivity. Connection promotes greater collaboration with, and among, customers, suppliers and partners. Last but not least, increased transparency means that middlemen and brokers are less likely to fleece someone in the regions!

Modern communication

The nature of communication is changing, too. Whereas, historically, communications have involved a point-to-point, one-to-one and (apart from telephone calls) normally unidirectional provision of information, the internet is now about two-way communication and interaction. That means that our connections need to be symmetrical: we need high volumes in both directions. They need to be low-latency: on a phone call, a long lag between you saying something, them hearing, them answering and you hearing, then answering, comes out as a pause which destroys conversation. They need to be high speed because we are using lots of data in multimedia applications.

The internet is also increasingly mobile. According to the Boston report, one-fifth of the world has a fixed-line broadband connection at the moment. Four-fifths of the world is within range of a mobile phone tower, and this will increase dramatically in the next 10 years.

Professor Michael Fourman FRSE chaired the *Digital Scotland* report. Currently a professor in the Centre for Intelligent Systems and their Application in the School of Informatics at the University of Edinburgh, he has held positions at Oxford and Brunel, as well as at Clark and Columbia universities in the USA. His research interests include formal models of digital systems and system-design tools, amongst other issues.

In 2001, the Scottish Government published *Connecting Scotland*. That report identified the lack of trunk capacity as a real constraint on economic development in island and remote rural areas. It examined five small towns and the bandwidth that would be needed to supply the populations of those towns. A great deal of the demand was generated by the public sector. Slightly less was due to consumer use, but these were still in tens or hundreds of Mb per second. That report led to two more initiatives: *A Study into Broadband Reach in Scotland* and *Pathfinder.* Pathfinder brought broadband to every school. Broadband Reach made broadband available to every community in Scotland with, in practice, everyone getting at least a third of a Mb per second.

Current UK policy will result in a widening of the digital divide. Significant parts of Scotland lag 10 years behind the internet speeds available to consumers in well-provided metropolitan areas. Instead of catching up, current UK policy defers *Digital Britain's* 2012 target, of universal access to 2Mb per second, to 2015. Scotland needs a digital strategy because current UK policy will inflict lasting damage on communities outside the core metropolitan areas. Scotland will suffer disproportionately by virtue of its human and physical geography.

Optical fibre

If we want to recreate the original vision of a digital society we should be aiming to keep pace with the world, avoiding the creation of connected 'haves' and 'have-nots'. For that we need optical fibre. Every community of more than 2,000 people should have access to a fibre network.

We need to extend the core network to deliver next generation broadband into community hubs. This will stimulate local communities, companies and local government to create access networks that can reach every business and dwelling in Scotland. Such an initiative will require an infrastructure strategy, together with a rating regime and regulatory environment, that focus on establishing a network with a long life that will stimulate sustainable investment and entrepreneurial activity.

We also need to ensure digital inclusion by motivating people and developing the skills to enable participation. We need to create hubs that will allow under-served communities and those without a personal connection to access the network. This will require local hubs, based in existing facilities such as libraries and community centres, which will provide walk-in and wireless internet access, which can serve as connection points for fixed and mobile local access networks and which will be a source of support and advice on safe and effective use of the technology.

We looked closely at the five small towns studied in the Connecting Scotland report and revised the amount of bandwidth we need to deliver internet to each of those towns in the light of new developments.

Consider a typical community of around 2,000 people – i.e. one per cent of Scotland's population. That would mean around 800 homes at an average occupancy of 2.5. Some 70 per cent of Scotland's homes are in communities that would be less than half a kilometre from a local fibre-optic hub. An even larger proportion – 86 per cent – would be within one kilometre and 99 per cent within 12 km. In fact, 2500 km of additional rural fibre would bring fibre

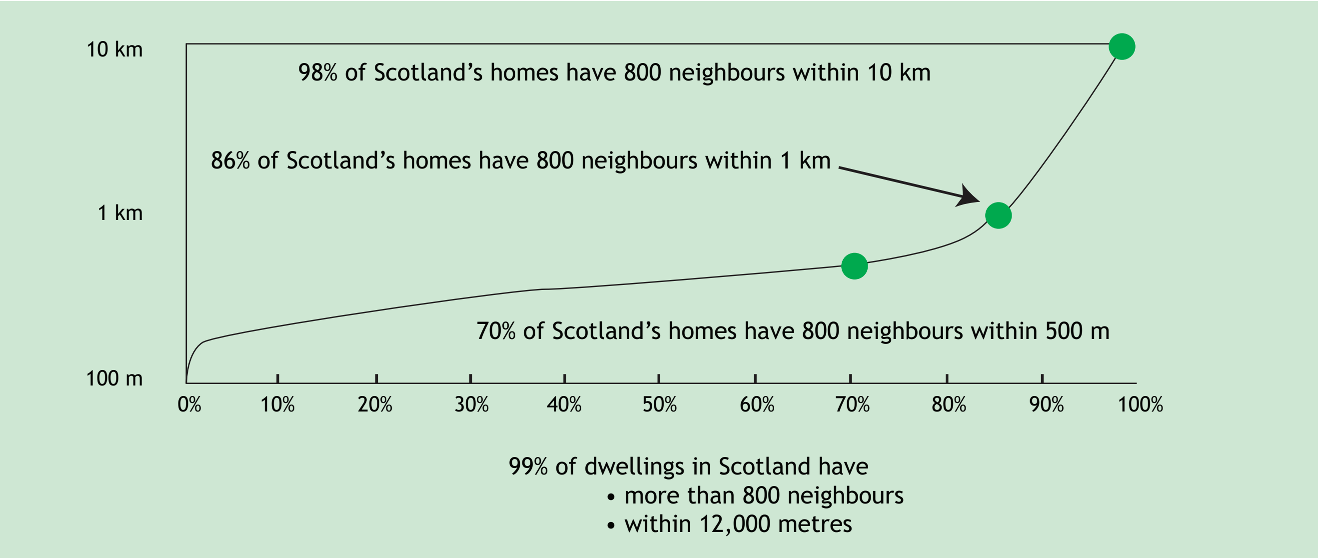


Figure 1. Proximity as a factor in planning digital networks

within reach of everybody (see Figure 1).

The capital cost of this network would be £100 million. In addition, there would be annual operational and maintenance expenditure: that means to build and operate it for 15 years would require £250 million. This is a small sum in the context of the benefits to be won and the available sources of finance (governmental and private). Government could also stimulate a thriving local digital economy through its procurement of software and services. In addition, open-data policies would increase the capital to be gained by local businesses building added-value services through the use of public data.

Digital Scotland Trust

We need a body in Scotland which will take charge of this. We have suggested that this might be a Digital Scotland Trust. We do need to engage with the UK Government and Ofcom, because many of the regulatory issues have already been dealt with. The situation is getting better already.

We need to enable universal digital inclusion. This network brings more than just a point of physical connectivity. It also creates a point of human connectivity for the local population – where those who do not have their own private connection can access the internet, and where schoolchildren who do not have access at home can take advantage of it in a socially supported place.

We recommend minimum speeds for 2Mb/s in 2010, 16 in 2015 and 128 in 2020. Median speeds at these times should be 8, 84 and 512 Mb/s respectively. On an international scale, these are modest goals. Finland is committed to providing universal access at 100Mb/s by 2015. ☐

Digital Scotland: www.rse.org.uk/enquiries/Digital_Scotland/index.htm

Connected Kingdom: www.connectedkingdom.co.uk

Connecting Scotland: www.scotland.gov.uk/Publications/2004/06/19531/39251

A Study into Broadband Reach in Scotland: www.scotland.gov.uk/Publications/2006/12/20130045/0

Pathfinder programme: www.scotland.gov.uk/Topics/ArtsCultureSport/arts/CulturalPolicy/workinggroup/Pathfinder

Digital Britain: www.official-documents.gov.uk/document/cm76/7650/7650.pdf

ICT in the public sector in Scotland

John McClelland

I was asked by John Swinney, Cabinet Secretary for Finance and Sustainable Growth in the Scottish Government, to look at information and communications technology (ICT) in the public sector, and within that the creation of a vision for ICT across the sector in Scotland. It is likely that the life of a citizen in Scotland will, at some point in the future, be totally supported by internet technology.

It is important to start with the needs of the user. Whether it is operating a small business, or just being a citizen and interacting with the local authority, health – including doctors – education or leisure, the ability to have that interaction and be served and initiate service, should be one which is completely and totally supported by the internet.

Practical examples

It should be possible to complain about services such as street lighting, or pay council tax and make benefit claims using the internet (it is already possible to renew car road tax in this way). Doctor's appointments – making them, rescheduling them and cancelling them – should all be possible online. As a person moves from home to home, from local authority area to local authority area or from health board to health board, personal (sometimes life-preserving) records should be transferred immediately from one area to the other.

In areas where there is an overlap, and perhaps a very essential interaction between different services, the interaction in that overlap needs to be seamless. For example, in the case of vulnerable children (an area which is covered and addressed by health services, by police and by local authorities), there should be a seamless and immediate information flow between these various authorities.

The ideal would be for each citizen to have a single smart card allowing

John McClelland CBE FRSE chairs the Scottish Funding Council for Further and Higher Education. He has extensive experience in both the private and public sectors. He has been Vice President of Worldwide Operations for IBM's personal computer company and also a former Chairman of the Renfrewshire Enterprise Company. He is a Vice President of the Royal Society of Edinburgh.

them access to services, rather than a bag full of different cards and technologies and an obtrusive set of accreditations and authentications which have to be completed each time they wish to claim their entitlements or access services.

The public sector

Focussing on the use of ICT in the public sector, there is a popular misconception in both the private and the public sectors that it is 'all done', that business processes are already automated, the use of ICT is very extensive and that nearly every job is carried out through digital technology or some equivalent level of automation. Of course, that is not the case.

Initial investigation indicates that ICT in the public sector should be more embedded than it currently is. Scotland spends a substantial amount of money on this and while it does not under-spend, there is room for debate as to whether that investment achieves the greatest value. Two-thirds of the budget goes to external suppliers, yet within the public sector there are probably about 6,000 ICT professionals and support staff.

The prevalent model is a stand-alone, self-sufficient IT function in each individual organisation. Some of those bodies are very well served, others less so, but again the prevalent model is to focus inwards on one's own organisation. There is little evidence of a shared service environment although there are some exemplars.

In health, ICT is very advanced in some areas and not so advanced in others. There are some commonalities in what health boards do. There is some shared hosting of data centres. There are some new, quite dramatic and sophisticated health applications being introduced, and it is very important that these should be shared applications as we move forward.

It is important to ensure the seamless transfer of information and availability of information. That could include information held by your health service, information associated with the police or other fiscal or Governmental organisations. This information must remain accessible to people as they move or travel – or find themselves involved in an accident or other incident. Those capabilities or services could be life-saving, as I have mentioned before.

Fractured governance

There needs to be governance, control, management, leadership and direction. Those involved in and associated with the public sector recognise that there is no central, overall governance model for it. Within the Scottish Government there are dozens, you could say hundreds, of different departments and agencies. There are 32 local authorities, 20-odd health boards, 60 colleges and universities. With so many organisations taking decentralised decisions and driving a decentralised architecture, this can be expensive both internally and for the citizen.

There is a great deal of vertical bundling of services: one provider may take responsibility for everything from the pipework and cabling right through to maintaining desktop equipment, while another may provide some combination of the organisation's requirement. It is a real challenge to ensure the very best service, the very best price. The complexity of multiple organisations and specifications means working with industry is very fragmented. I would argue that there needs to be more coming-together in this area and more aggregation of procurement.

In addition, new technologies are not fully exploited. Voice-over internet protocol (VoIP) technologies are being used in some cases, but not all. Teleconferencing, effective from a cost point of view but also from a sustainability standpoint, is in use in the public sector, but not extensively.

Commitment

The public sector in Scotland should now move to 'cloud computing' which is the central hosting of shared applications. Broadband speeds are making this possible, and it will offer a major opportunity to be more effective so long as we can take that technological step.

However, taking real advantage of this will need change, it will need management, it will need leadership and it will certainly need, in the context of the public sector, a very clear commitment to make the public sector as advanced as it can be in the use of ICT. I hope that it will also bring a spin-off to the private sector and to the individual citizen. ❑

The promise of IT innovation

Rashik Parmar

Technology has really come a long way in the last half century. The raw infrastructure for information technology (IT), the transistor, was born in 1947. In those days it was about 4 cm high. We are now at a point where there are a billion transistors for every person alive. Yet the connection between that IT technology and being able to use it is a tiny little pipe – a tiny broadband pipe, one of the most fundamental bottlenecks in the way we exploit that technology today.

A changing world

Over the last 10 to 20 years, many cities across Scotland have addressed the challenge that their major manufactured goods have changed into commodities bought and sold around the world. At the same time, this presented an opportunity to transform these manufacturing industries into service industries. We are lucky today that, although manufacturing has declined to 23.8 per cent of the GDP of the United Kingdom, service industries represent 75 per cent. We all know that those service industries too will become commodities – we just do not know when or how.

That is the challenge the Scottish nation needs to address. That is the opportunity that exists. We see jobs moving overseas to India and the cheaper labour there as one of the big opportunities for cutting costs. We see services move out. So, is that really turning services into commodities? Absolutely not.

Work done by people in the services sector is being transferred into software. As that is created, a number of things happen. We benefit from economies of scale which allow us to provide that same service for a fraction of the cost and to a much broader population: we can actually offer that service globally. We can start to apportion cost and value from our services back into the place where that service and that capability were created.

So I see two principal opportunities for Scotland here. One is the creation of some of this software which is transforming service industries as we know them today. This is a fabulous opportunity and the talent exists within Scotland. The second opportunity is to take that software, run it and provide services for the world, based out of Scotland. We have the climate, we have the opportunity, we have the ability to do that as well.

One of the biggest bottlenecks is that the current fibre networks will not allow us to connect to the world in such a way as to be able to provide those kinds of services. That is one of the issues we must address.

Challenges for cities

There are a range of challenges facing cities today, from transport – and so many of our cities are choked with traffic – through the provision of affordable housing, to bridging the digital divide.

IBM's Academy of Technology makes effective use of IT infrastructure. Each year it holds its own AGM, bringing together around about 500 technical leaders from IBM around the world in a virtual conference. That virtual conference is only possible because we have high-speed bandwidth across our IBM locations.

During the latest AGM, I happened to be in a hotel in Winchester and I could not connect to the conference. I could not see the video images. I could not even access some of the voice being transmitted by leaders around the world as we discussed the agenda that we would drive for the next two to three years, providing leadership for the IBM company. I was unable to participate because the bandwidth provided in that hotel was not sufficient to allow me to access those services.

I really understood the frustration which many people across Scotland now feel because they are not connected to that digital infrastructure.

Rashik Parmar is Chief Technology Officer for North East Europe for IBM. He is a Distinguished Engineer and a member of the IBM Academy of Technology, responsible for the development and execution of technical strategies, and the vitality of the technical community. He is an Adjunct Professor for Department of Innovation and Entrepreneurship at the Imperial College Business School.

The previous year, in my office in Leeds, I had full access. I could use virtual networks to brainstorm and my avatar could go and put my ideas up on a wall. I could use the video capability to see real-time, high-quality video of the leaders who were in the USA talking about some of the issues that we faced.

Information technology, in the shape of sensors, also allows us to tackle other issues facing cities, such as urban transport. Take Stockholm for instance. Through congestion charging, that city has not only reduced travel times, it has reduced traffic, CO_2 levels and the fatality rate. The initiative has actually rekindled the centre of Stockholm and created a much more vibrant retail infrastructure there. Nobody would have predicted that.

It happened because the city authorities could sensor every single bridge, could apply a technology which allowed them to monitor every car as it went through a toll bridge and decide whether it was going to get charged or not. The sums involved were a fraction of the value created in the retail infrastructure alone, let alone the quality of life improvement from dependable transport networks.

The smarter city is much closer to bring a reality today.

Constrained by bandwidth

Information technology can take real data, transform many systems at city level and make them smarter. The constraint we have is the bandwidth between the sensors – the information sources.

We should leverage some of the opportunities that many of the cities have today to build a platform for innovation where small and medium enterprises can create our next mega-businesses.

Look at Aberdeen and the capabilities it is starting to develop in renewable energy. They will not be successful in delivering the promise of renewable energy unless the IT infrastructure is also in place. We need it for effective management of the various information sources, so that we can choose which power source we are using and make effective use of all the renewable energies.

Bandwidth constraints may also impact on the ability of Dundee to maximise its capabilities in medical imaging and medical systems. Insufficient bandwidth prevents us from moving the required volume of data and information from clinical trials, and impairs the efficient capture of medical data that exists inside the university in Dundee.

It will not be possible to drive the reduction in carbon that sustainable Glasgow expects if we cannot get the data from the sensors fast enough to be able to make the appropriate decisions.

The public sector, too, has a tremendous opportunity right now. The opportunity is to rethink how to deliver services – using IT capability to transform the services that the public sector provides, creating shared-use services that can really deliver and transform capability for Scotland. If this is done well, Scotland can lead the world and export some of those services, not only to the UK, but also to Europe. We should be seizing these opportunities right now. ☐

DISCUSSION

Government commitment

The analyses and recommendations in the Digital Scotland report are of wider significance than for Scotland alone; they have a resonance for the whole of the UK, with the references to communities and encouraging local participation. These should be brought to the attention of UK ministers. And the recommendations for the strategy plan require active participation by Government. But how likely is such participation? Public understanding of the importance of digital connections is poor; this has been demonstrated in many areas by poor take-up. There are divergent views in Government on the priority which should be given to digital infrastructure, and how to go about it.

Biofuels could have a key role to play in meeting the UK's carbon reduction commitments. But how viable is a long term UK biofuel industry? The issue was discussed at a meeting of the Foundation for Science and Technology on 6 April 2011.

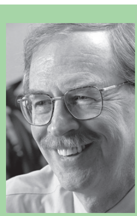
Achieving the renewable energy target

Bernie Bulkin

The Renewable Energy Strategy launched by the Government in 2009 set the target of achieving 15 per cent of the country's energy, or 235 terawatt hours per year (TWh/y), from renewable sources by 2020. This is the overall goal, but to achieve it there must be a working plan that maps out exactly what steps to take and when to take them.

A combination of technologies will be needed to meet or exceed the goal, so the approach was to look at each technology separately in order to ascertain its potential contribution to the total. Market participants from 22 renewable technologies were asked to estimate what the minimum, maximum and central contributions to renewable energy from their approach were likely to be. In addition, they were asked to estimate by how much they might be able to increase their contributions over two-year intervals to 2020, and what barriers needed to be removed or incentives created to enable them to achieve these estimates.

Biomass will provide about half the UK's renewable energy, supplying electricity and heat, as well as fuel for transport. Further heat will be provided by ground-source and air-source heat pumps. Offshore and onshore wind will be used much more extensively than now. These seven technologies together should yield 210 TWh/y. Hydropower and landfill gas will supply another 10 TWh/y. Photovoltaic, solar thermal, tidal stream and wave power energy will be brought into play, and electric vehicles will also make a contribution.



Dr Bernie Bulkin is the Chair of the Office for Renewable Energy Deployment at the Department of Energy and Climate Change (DECC). He is also the Chairman of Chemrec and a board member of Severn Trent, Ze-gen Corporation and REAC Fuel. He is a member of the FTSE Environmental Markets Advisory Committee and a Professorial Fellow of Murray Edwards College, University of Cambridge.

Electricity and heat

Biomass is expected to fuel a significant proportion of the country's renewable electricity. When the Renewable Energy Strategy was launched it was estimated that biomass electricity would account for 9.4 TWh/y, but it is now clear this will be much higher. A large number of dedicated biomass plants, co-firing and conversions have been proposed which would enable very rapid growth in this form of electricity.

The costs of generating large-scale electricity from renewable sources vary. Electricity from onshore wind has potential to be comparable in cost to gas. Offshore wind is significantly more expensive. Large and small biomass power projects are relatively competitive.

To achieve the renewable heating goal, some 9,000 commercial and 310,000 domestic biomass boilers would be needed. There remain a number of unanswered questions about how this will be achieved – for example, how will the supply chains be set up? Right now attention is being focussed on the non-domestic sector, where a high percentage of biomass heating can be achieved. Projections indicate that, except for solar thermal heat, most of the renewable heating technologies (air-source heat pumps, biomass boilers, biomass district heating, ground-source heat pumps and biogas injection into the grid) could be cost-competitive with conventional gas heating by 2020. So there is an opportunity for a significant amount of renewable heat by 2020.

Fuel for transport

Current Government policy only extends to 2014, after which time the picture becomes unclear. Policy decisions are needed in this area. The target for 2020 is to obtain 10 per cent of transport energy from renewable sources.

In my view we have four choices:

- carry on as we have been doing, using more biodiesel and bioethanol. This is a technically safe option (there is enough capacity in the market to build plants to supply the fuel) but there are questions about sustainability;
- rely on technological advances in biofuels to make them commercially viable on a large scale;
- concentrate on biofuels for aviation, shipping and possibly heavy goods vehicles, rather than passenger cars and light goods vehicles;
- aim for vehicle electrification, building the necessary infrastructure and coupling that with maximum low-carbon electricity.

Meeting the target

The UK will meet its target, one way or another. Choices will depend on decisions that still need to be made on issues such as: land use change; waste minimisation versus waste utilisation; and benefits to the UK in terms of jobs. Much activity is taking place at UK Government and EU levels to develop biomass policy. The UK is positioning itself to meet the 15 per cent target and then to go further in the decade beyond 2020. ☐

Office for Renewable Energy Deployment (ORED), Department of Energy and Climate Change: www.decc.gov.uk/en/content/cms/what_we_do/uk_supply/energy_mix/renewable/ored/ored.aspx

DISCUSSION

Looking beyond 2020

The targets for 2050 assume an 80 per cent reduction in CO_2 emissions. Will meeting the 2020 targets provide a robust path to 2050, given that the world population is expected to rise by one third? Perhaps more importantly, we should be considering the effect of these targets more broadly, looking at the impact on biodiversity, land rights and tenure, public demand and population spread, and regulations needed to achieve the desired results. A policy that considers all of these factors will be the only way to secure achievement of the targets.

The global growth in biofuels

James Primrose

James Primrose is Global Strategy Manager at BP Biofuels, where he and his team are responsible for the ongoing evolution of BP's global biofuels strategy. He is a board member of Bonsucro, an initiative aimed at developing a sustainability standard for sugar and ethanol derived from sugar cane. He is also a trustee of the UK's Low Carbon Vehicle Partnership.

Biofuels are the fastest growing liquid fuel. By 2030 biofuels are expected to account for the equivalent of 6.5 million barrels a day of oil. To give an idea of the scale, that would put biofuels in fourth place behind Saudi Arabia, Russia and the USA, the three top oil producers today. Biofuels already account for about 5 per cent by volume, or just under 3 per cent by energy, of all the liquid road transport fuel used in the world.

This reflects the key advantage of biofuels: they are compatible with the existing vehicle fleet and fuel supply infrastructure. This is very important given the long turnover frequency of the vehicle stock (the average lifetime of a car is 12 years in Europe and 18 years in the USA) and costs and time associated with the provision of new fuel supply infrastructure.

The two factors pushing the growth in biofuels are the need to reduce CO_2 emissions and the need for energy security. Unfortunately there are no 'magic bullets' for tackling the CO_2 issue, and various technologies have been in and out of favour. Five years ago, hydrogen fuel cell vehicles were being hailed as the technology to watch. At that time serious commentators were predicting that such vehicles would be commercially available by 2012. Today, electric vehicles have taken over as the technology promised for the future. In reality, it is likely that a combination of technologies will be used and the internal combustion engine is likely to be powering vehicles for years to come, securing the future for liquid fuels and emphasising the need for biofuels. Advances in the combustion engine together with the use of mild to full hybridisation can deliver a reduction in CO_2 emissions equivalent to, and sometimes exceeding, that delivered by dedicated battery electric vehicles – at a substantially reduced cost to the consumer and using a less risky technology. So, it is not a case of choosing between biofuels and electric vehicles, but of using a combination of technologies.

'Good' and 'bad' biofuels

It is vital to differentiate between 'good' and 'bad' biofuels. To do so, four criteria can be employed:

- Cost: a biofuel must have a low cost in order to be competitive with conventional fuels. The industry cannot depend on regulatory support over the longer term. Sugar cane ethanol today is cost competitive with oil at about $40 a barrel. Cellulosic ethanol is expected to reach that point by 2020 after significant reductions in the cost of the enzymes coupled with lower feedstock costs through yield improvements;
- CO_2 emissions: these must be low on a life-cycle basis;
- Scaleability: it must be possible to deliver biofuels on a significant scale, globally;
- Sustainability: regulatory support for biofuels requires that they must be sustainable, but not only in terms of CO_2 emissions. Account must also be taken of water use, biodiversity and social factors.

BP has a twofold strategy to meet these criteria. The first part is to increase the yields of biofuels, while the second is produce new fuel molecules which are more compatible with existing fuels and vehicles.

In 2008, BP purchased a 50 per cent share in a sugar mill ethanol plant in Brazil. Since then, a further three mills have been acquired, two that are operational and one under construction. Together these four mills, when fully developed, will produce the equivalent of about 1.4 billion litres of ethanol every year. As well as producing ethanol and sugar, these mills will also have powerful cogeneration facilities, generating power to fuel ethanol production and exporting surplus electricity to the grid.

In 2010, BP acquired the biofuels business of Verenium, a leader in the development of cellulose ethanol technology. This has provided BP with a world-class research and development facility in California and a cellulosic demonstration plant in Louisiana. A commercial-scale cellulosic ethanol plant is currently under construction in Florida with a capacity of 136 million litres of cellulosic ethanol produced from energy grasses.

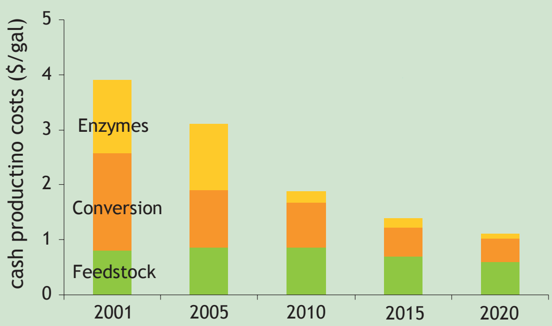


Figure 1. Changing production costs for cellulosic ethanol production.

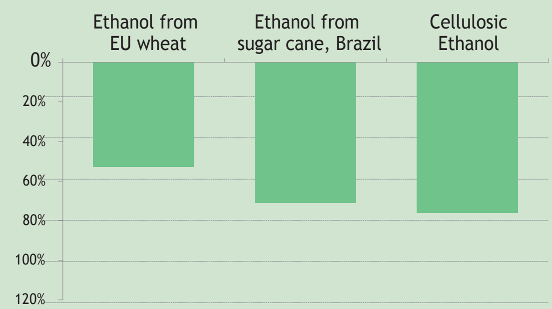


Figure 2. Greenhouse gas reductions, biofuels v gasoline.

Source: EU Renewable Energy Directive Annex V, 2009.

DISCUSSION

Will the public accept biofuels?

It will not be easy to persuade people that they will get the same performance and reliability from their cars as they are used to with conventional fuel. The German experience is instructive – a major effort to persuade the public to use hybridised fuel has collapsed amidst a media storm after defects appeared. The public need to understand the difference between 'good' and 'bad' biofuels. The strongest incentive for public acceptance of biofuels will be high oil prices and a belief that they will stay high.

Improving the structure

Here in the UK. a biobutanol technology demonstration plant will soon open in Hull, to demonstrate the commercial use of biobutanol. Alongside that a BP joint venture will also be producing bioethanol from locally-grown feed-grade wheat. BP is looking at producing biobutanol from a range of feed stocks – wheat, sugar cane, corn and cellulosic feedstocks. This work is augmented by a relationship with the Energy Biosciences Institute at the University of California and the University of Illinois.

Low-cost, low-carbon biofuels have a key role to play in reducing CO_2 emissions in the transport sector. The most promising advanced biofuel technologies are on the cusp of being deployed on a commercial scale and show the potential to be cost-competitive within the next 10 years. Done well, biofuels can be a crucible for the wider agricultural sector in terms of environmental and social sustainability benefits.

However, biofuels policy in Europe is still highly fragmented and subject to a large degree of uncertainty. This uncertainty significantly increases investment risk, forcing investors to demand higher levels of return, which will ultimately be paid by consumers and taxpayers. Europe needs to establish a successful and sustainable biofuels sector that can act as a platform for the deployment of advanced biofuel technologies. ❑

Biorefining in the UK

Sam Cockerill

Sam Cockerill is Business Development Manager at Ensus. He has co-authored a number of scientific papers on the sustainability of grain biorefining. He is a chartered mechanical engineer and has worked in technology development, general management and strategy consulting roles for 18 years. Sam is also a non-executive director of Providence Holdings, one of the UK's major agricultural supply companies.

The feed wheat used in the biorefining process is about one-tenth protein and two-thirds starch and sugar, mostly fermentable plant materials. It also contains fibre, oil and other materials. The bio-refining process is very similar to that of a whisky distillery. We take the grains, mash them up, add enzymes and run them through a fermentation process that converts most of the starch and sugars into bioethanol and CO_2. The fermentation process is remarkably efficient. It barely wastes any energy as very little heat is produced in the biological conversion step. About 95 per cent of the energy in the starch and sugars is concentrated directly into the biofuel. CO_2 is released in pure form and sent off to be compressed into a liquid state. That liquid is then used in food production, for example in fizzy drinks, in horticulture, and in various other industrial capacities.

CO_2 is captured on a very large scale but it is a very-low cost capture operation – it is not being separated from nitrogen, water vapour and other flue gases as would be necessary in a coal-fired power station. In future, when the UK has an industrial carbon capture and storage (CCS) infrastructure, it is likely that plants like the Ensus biorefinery would be able to make a significant and cost-effective contribution to CO_2 supply into that infrastructure through this low-cost, biogenic carbon capture step.

Ensus uses UK-sourced animal feed wheat and produces enough bioethanol to meet over half of UK demand: in that context, it is a very significant player. It is one of the largest such plants in Europe and the bioethanol is produced with a very good carbon saving, saving over 70 per cent of the greenhouse emissions that would be produced by the gasoline replaced, on a direct basis. This comfortably exceeds both the current EU Renewable Energy Directive sustainability requirement of 35 per cent carbon savings and the 2017 requirement of 50 per cent.

Producing a greener food chain

In the Ensus process, everything not converted into ethanol or CO_2 becomes animal feed. This is called DDGS, dried distillers grains with solubles. No waste or effluent is produced. DDGS is a particularly useful material because the protein in the feed wheat is entirely disregarded by the yeast as it goes through fermentation – in fact, the growing yeast adds to the wheat protein by incorporating nitrogen from urea and ammonia added to the process as nutrients.

So the animal feed produced has slightly more protein than the feedstock, but because the sugar and starch have been removed, the animal feed at the end of the process has a high protein content

DISCUSSION

Lack of investment in biorefining

There was particular interest in the Ensus process. By coupling bioethanol production with high-protein animal feed, it meets the needs of two markets, although those needs may peak at different times. A great advantage of the process is that it uses UK wheat production and meets farmers' requirements. It would be expected that investors would want to fund similar types of process, but they have not yet been willing to do so. Until entrepreneurs can show convincingly that these plants are profitable within a set time period, investment will not happen.

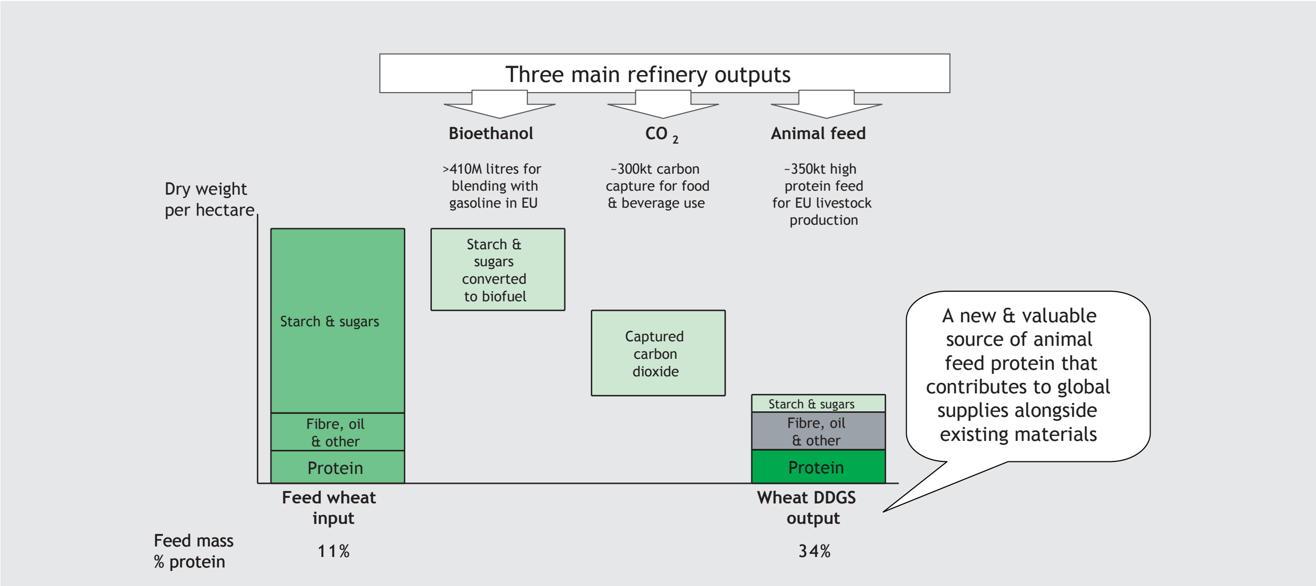


Figure 1. The biorefining process

– around 35 per cent. This co-product adds to European and global supplies of high-protein animal feed and it competes in the feed market on the basis of its nutritional value. Europe imports a great deal of soya meal for animal feed. The livestock industry globally is responsible for about one fifth of greenhouse gas emissions, and much of that stems from the production of feed and the conversion of high carbon stock land area required to produce that feed, especially in the tropics. DDGS makes an important contribution to sustainability in the livestock industry by reducing EU demand for imported soya meal from South America.

Second-generation technologies

Replacing more than about 20 per cent of global transport fuel energy will require second-generation biofuels. These will be made from cellulosic plant materials and may employ feedstocks other than sugar crops and grains; for example, grasses and woody energy crops, forest thinnings, wastes or algae. Second generation biofuels are typically more expensive than first generation biofuels because of the necessary additional capital investment, process operating costs and supply chain logistics costs per unit of fuel energy produced.

The 'first-generation' bioethanol industry provides a capital-efficient route to second generation bioethanol production, within existing biorefining facilities, and with no additional logistics costs, by converting cellulosic components in current feedstocks already in-process. It also provides a basis for new process developments that will pave the way for future second generation biofuel production pathways that can make economic use of new feedstocks and new biomass supply chains.

Grain biorefining has three very important benefits:

- it provides an immediate, highly sustainable contribution to achieving UK and EU targets on climate change and a greener food supply chain;
- it improves food and energy security, adding to global supplies of high-protein animal feed and transport fuel;
- it is an essential platform for future green technology development. □

Carbon dioxide - an age-old problem

Douglas Kell

There was a time, millions of years ago, when the amount of CO_2 in the atmosphere was even higher than it is today – about 10 to 20 times higher. The problem was solved by the evolution of trees and flowering plants that sequester carbon and by the laying down of coal. A great deal of research today is focussed on harnessing the power of plants that are good at sequestering carbon – bioenergy plants. Sequestering carbon in the soil as part of growing biomass crops is a vital part of reducing CO_2 in the atmosphere, and is an additional benefit to creating the biomass itself.

Professor Douglas Kell is Chief Executive of the Biotechnology and Biological Sciences Research Council (BBSRC). Professor Kell studied biochemistry and bioenergetics at Oxford University. He has worked on the development of analytical and computational models at the University of Aberystwyth. He later moved to Manchester as Chair of Bioanalytical Science. He also chaired the 2006 BBSRC review of bioenergy.

The amount of CO_2 in the atmosphere today is 385 parts per million by volume (ppmv). This is rising at a rate of some 2 ppmv per year. By comparison, the 'pre-industrial' level was 280 ppmv. Yet, if we could increase the carbon density in the soils of all the crops and grasslands in the world by 1 per cent through creating an extra metre of plant root, over 100 ppmv of CO_2 could be removed from the atmosphere.

Biofuel crops in the UK

Although the UK is relatively small, accounting for roughly 1 per cent of the world's land area, it is the leading nation in plant sciences. Our researchers are looking at a number of potential

DISCUSSION

The risks in changing land use

If farmers are to commit to growing specific crops for biofuel, they will need safeguards against the risk of being overtaken by technological changes that necessitate a different crop or a different means of production. Other risks include continuing water shortages and efforts to restrict the use of pesticides. Whatever incentives may be put in place, there will always be the danger of creating perverse incentives leading to undesirable effects. Some people may resist crop change if it affects the landscape.

biofuel crops, some of which have both edible and non-edible components. They include waste in many forms, dual food/fuel crops such as cereals, straw and sugar beet, short-rotation coppice willow, and Miscanthus grass.

Because of our relatively small land mass, using the land effectively is a particular challenge. The UK comprises approximately 25 million hectares, with over 10 million hectares in England. When land in lakes, rivers, cities and other areas that cannot be used is subtracted, the total in England is under 8 million hectares. When other land that may not be usable is also taken out of the equation, for example national parks and areas of outstanding natural beauty, the total falls to less than 5 million hectares.

However, in England we have about 3.1 million hectares of agricultural land that is graded 3 or 4, representing among the least attractive land for agriculture. We need about 350,000 hectares to meet our transport biofuel obligations– or just over a tenth of the land that is of limited value for agriculture.

In addition, the proportion of land in the UK that is currently used for non-food crops such as forests is 12 per cent, whereas in Germany the figure is 30 per cent and in Sweden and Denmark it rises to 65 per cent. Thus in the UK we have a higher proportion of land area that we can still use for non-food crops, an opportunity not available in other European countries.

While having the land available is important, yield per hectare is also crucial. Most plants we grow have a photosynthetic yield of 1 per cent. In comparison, theoretical yields for C3 and C4 plants (which represent different kinds of photosynthesis) have been calculated to be 5 per cent and 7 per cent respectively. Based on these calculations it is clear that there is much potential to improve yield. Historically, we have improved our yield of grain by about 1-3 per cent every year and that is an easily attainable target for biofuels as well.

Yields vary typically between five and 15 tonnes per hectare. The variation is partly genetic and partly agronomic. We base our current yield calculations on 12.5 tonnes per hectare, and we are hoping almost to double that amount. The key to achieving this lies in genomics. We can now sequence anything we might wish to breed within a very small amount of time. In the beginning it took scientists many years to sequence DNA. By January 2009, we had sequenced 200,000 million DNA bases (approximately 60 human genomes). The same amount of sequencing now takes one week and requires one machine. Facilities such as the Sanger Institute and the Beijing Genome Institute have 100 of these machines each. The speed with which we can now sequence large numbers of DNA bases represents a very important breakthrough in genomics-driven breeding.

Using the knowledge acquired by sequencing to determine the traits we need to breed is a very important challenge for the future. We need to create multiple cultivars with the right traits; these include ease of breakdown as well as resistance to disease and drought.

A knowledge-based bioeconomy

For reasons to do with infrastructure, it is sensible to start by making liquid transport biofuels, whatever else we may do in the long term. Ethanol is the front runner at the moment, but its carbon:hydrogen:oxygen ratio is not particularly good. Other possibilities include making hydrocarbons from algae or other matter, which is how they were made first time around, millions of years ago.

When the oil and coal finally run out, and preferably before, we will need to use similar processes to make other products as well. In Europe this is called the knowledge-based bioeconomy. At its centre is the sustainable intensification of agriculture to fix carbon.

The BBSRC Sustainable Bioenergy Centre in Aberystwyth and elsewhere is conducting a trial planting of one of the energy grasses. The Centre is a 'virtual' research centre in which five universities and research institutes are involved. It has received funding of about £26 million from the BBSRC and a number of companies. It carries out research into ways of optimising yields by optimising each individual component – not only biomass growth, but also composition, deconstruction and fermentation. For example, the amount of sugar we can obtain from sugar cane could be much larger than it is now. The same is true of other, cellulosic biomass fuels. Improving the composition of these to maximise extractability is a vital part of our work.

Another promising area is that of novel enzymes. One of the classes of enzymes we are looking at comes from an organism known as a marine wood borer, or a 'gribble'. Unlike termites, which use bacteria in their stomachs to grind away wood, wood borers themselves encode and possess enzymes that make cellulases. The discovery of these enzymes is leading to some very exciting work.

Other research involves finding ways to improve yield, efficiency and extractability in the fermentation process – for example, by varying the temperature.

The ability to sequester carbon while creating vital biomass is a prize well worth seeking. Bioenergy crops are much better at sequestering carbon than are other crops such as winter wheat and oil seed rape. Soil contains twice as much carbon as the atmosphere. We must put policies in place that give farmers an incentive to plant bioenergy crops. We know that the plants we need exist – the rest is up to us. ❑

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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

The UK National Ecosystem Assessment

13 July 2011

Professor Bob Watson CMG FRS, Chief Scientific Adviser at the Department for Environment, Food and Rural Affairs

Public procurement as a tool to stimulate innovation - the House of Lords Science and Technology Select Committee Report

22 June 2011

The Lord Krebs Kt FRS FMedSci Hon DSc, Chairman, House of Lords Science and Technology Select Committee
Darren James, Managing Director Infrastructure, Costain
Sally Collier, Executive Director, Procurement Policy and Capability, Efficiency Reform Group, Cabinet Office
Professor Brian Collins CB FREng, Former Chief Scientific Adviser, Department for Business, Innovation and Skills and Department for Transport

Can better use be made of public data for example in health research?

8 June 2011

Professor Paul Boyle FRSE, Chief Executive, Economic and Social Research Council

Baroness O'Neill of Bengarve CBE FBA HonFRS FMedSci, House of Lords
Stephen Penneck, Director General, Office for National Statistics (ONS)

The Japanese earthquake, tsunami and nuclear accident - implications for the UK

18 May 2011

Sir John Beddington CMG FRS FRSE, Government Chief Scientific Adviser, Government Office for Science
Professor Nick Pidgeon, Professor of Applied Psychology, School of Applied Psychology, Cardiff University
Professor Laurence G Williams FREng, Former HM Chief Inspector of Nuclear Installations, Professor of Nuclear Safety, John Tyndall Institute, University of Central Lancashire
Dr Mike Weightman FREng, HM Chief Inspector of Nuclear Installations, Office for Nuclear Regulation, Health and Safety Executive

The future strategy for the management of mental health in the UK

4 May 2011

Professor Lord Layard FBA, Centre for Economic Performance, London School of Economics and Political Science
Professor Simon Wessely FRCP FRCPsych FMedSci, Vice Dean, Academic Psychiatry, Head, Department of Psychological Medicine, and Director, King's Centre for Military Health Research, Institute of Psychiatry, Maudsley Hospital, King's College London
David Behan CBE, Director General of Social Care, Local Government and Care Partnerships, Department of Health

Is there a viable future for biofuels in the UK?

6 April 2011

Dr Bernie Bulkin, Chair, Office for Renewable Energy Deployment (ORED), Department of Energy and Climate Change

James Primrose, Global Strategy Manager, BP Biofuels
Sam Cockerill, Business Development Manager, Ensus
Professor Douglas Kell, Chief Executive, Biotechnology and Biological Sciences Research Council

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

2 March 2011

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

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

10 February 2011

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

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

2 February 2011

Professor Sir Adrian Smith FRS, Director General, Knowledge and Innovation, Department for Business, Innovation and Skills

Professor Malcolm Grant CBE, President and Provost, University College London
Dr Patrick Vallance FRCP FMedSci, Senior Vice President, Medicines Discovery and Development, GlaxoSmithKline

The wonder of the Web

8 December 2010

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

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

24 November 2010

Professor David MacKay FRS, Chief Scientific Adviser, Department of Energy and Climate Change

Stuart Groves, Principal, Booz & Company

Pilgrim Beart, Founder and Director, AlertMe

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