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THE FOUNDATION FOR SCIENCE AND TECHNOLOGY

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Expanding university provision

A consultation to open up opportunities for towns and cities to bid for new university campuses and centres of higher education was announced by John Denham, Secretary of State for Innovation, Universities and Skills, on 3 March. Since 2003, 17 new higher education centres have been opened or have had funding committed. The Government wants to accelerate the pace of development and expects to have 20 more opened or agreed over the next six years, subject to high quality bids. Filled to capacity, the new 20 centres could provide study places for up to 10,000 students.

The consultation will be led by the Higher Education Funding Council for England (HEFCE). The Government wants to see more bids that successfully mobilise the support of local people, businesses and funding bodies including local authorities and Regional Development Agencies, all working with universities and colleges to boost the number of new centres.

Government funding for the new centres will be allocated from HEFCE's strategic development fund. In the Comprehensive Spending Review period, £150 million has been set aside for this. In addition it is expected that projects will attract funding from other sources.

A draft consultation document will be considered by the HEFCE board at its 8 May meeting. The formal consultation document will then be issued at the end of May. ❐

Ten year enterprise strategy

Funding to establish a national network of university enterprise clusters was announced by the Government on 12 March. The National Council for Graduate Entrepreneurship will receive additional funds for this purpose as part of a package of measures announced in a 10 year strategy designed to make the UK the most enterprising economy in the world – and the best place to start and grow a business. The strategy sets out proposals for the 'refocussing' of the Small Business Research Initiative (SBRI) which is now to be coordinated by the Technology Strategy Board. It will also investigate the role that innovation vouchers can have in encouraging firms to innovate in liaison with universities.

Enterprise: Unlocking the UK's Talent is published jointly by HM Treasury and the Department for Business, Enterprise and Regulatory Reform. ❐

www.berr.gov.uk/enterprisestrategy

Research Councils reject proposed RAE replacement

Research Councils UK (RCUK) has informed the Higher Education Funding Council for England (HEFCE) that the current proposals for replacing the Research Assessment Exercise (RAE) are unacceptable.

Although RCUK is supportive of the move towards more impact-based metrics in assessment, it does have two specific concerns. First, the assessment of impact proposed for science-based disciplines focuses solely on one dimension – academic impact measured through citations. RCUK argues that this is not consistent with Government policy and that other dimensions of research impact, such as user-relevance and the benefits to wider society, should also be included. Second, RCUK questions the 'twin-track' assessment approach of a qualitatively different method for science and non-science disciplines.

RCUK recommends that consideration is given to a unified approach across all disciplines that:

- draws on a full range of discipline–specific output metrics that measure research impact across a range of dimensions including academic impact, user-relevance and societal benefit;
- uses 'light-touch' peer review to evaluate those aspects of research impact that cannot be captured using qualitative metrics;
- uses expert opinion to select and weight metrics on a discipline-by-discipline basis. ❐

www.rcuk.ac.uk/news/070220a.htm

STFC reviews programme priorities

The threatened closure of Jodrell Bank observatory has once again pushed the funding shortfall at the Science and Technology Facilities Council (STFC) into the public spotlight. While Jodrell Bank is run by Manchester University and not the STFC, it carries out work on some of the STFC projects currently under review. Faced with a multi-million pound 'gap' in resources over the period of the Comprehensive Spending Review, the Council is seeking to prioritise its programmes for the future.

On 3 March it released the advice it had received from its Science Board and subcommittees which had been conducting a review of all STFC approved programmes. This biennial exercise is aimed at guiding the future evolution of STFC's programme by evaluating the scientific priority of each project, facility or activity and assessing its likely future productivity.

The release has been followed by an online consultation process which closed on 21 March. Over 1250 comments were received. These are now being reviewed by a number of small panels – representing specific research areas – who will make recommendations.

They are not being asked to repeat the programmatic review, but to comment on the outcome and to suggest how to implement it within the financial constraints. The STFC says they could make suggestions about the need to maintain a viable programme in particular areas of this committee's programme through limiting or sharing costs or – in critical areas – by reducing support for other projects in another area. This advice will be sent to the Particle Physics, Astronomy and Nuclear Physics Science Committee (PPAN) and the Physical and Life Sciences Committee (PALS) – and to the Executive. It is planned that the output from the panels will be made public. ❐

www.stfc.ac.uk/STFCConsultation/comment.aspx

'Science' back in remit of select committee

The Government has recognised the importance of cross-departmental scrutiny of science by the House of Commons by agreeing to change the new name of the former Science and Technology Committee. On 11 March, the body formally became the Innovation, Universities, Science and Skills (IUSS) Select Committee. ❐

Webcasts of Sir David King presenting his valedictory lecture to the 30th anniversary meeting of the Foundation for Science and Technology, and of Lord Sainsbury setting out details of his review of Government science and innovation policies, can be viewed on the Foundation's website at **www.foundation.org.uk**

A neutral forum for debate and reflection

Dr Dougal Goodman FREng, Chief Executive

The Foundation has evolved from its early beginnings as an umbrella body for learned and professional societies to a debating forum bringing together parliamentarians, Whitehall officials, business leaders and the research community. The Peers who established the Foundation in 1977 cleverly wrote into the constitution that it should be a neutral body and that the President of The Royal Society, the President of The Royal Academy of Engineering and the Chairs of all the Research Councils should sit on the Foundation Council. Over time the Foundation debates have focussed on policy issues that have a science, engineering, technological or medical element.

Since I became Chief Executive, I have tried to time the debates to coincide, where possible, with key Government policy decisions. In this issue Sir David King's valedictory lecture is summarised (see pages 17-21). The Foundation hosted the lecture to celebrate his time as the Government Chief Scientific Adviser (GCSA). Sir David and his predecessor, Lord May of Oxford, emphasised the importance of science advice in policy decisions. The Foundation has organised many meetings to assist the GSCA and departmental Chief Scientific Advisers in raising awareness of key policy issues that have a science element. It is sad that this issue also includes an obituary of Professor Howard Dalton, the former CSA at the Department for Environment, Food and Rural Affairs. Howard was a great supporter of the Foundation.

A wide range of issues

During my time as Chief Executive I have been able to organise debates on a wide range of issues but there are some that particularly stand out. In October 2000 the Foundation brought together researchers, politicians, religious leaders and others to debate the value of research on stem cells. This was held just ahead of the free vote in both Houses of Parliament at which the regulation of stem cell research was agreed.

A succession of meetings have been held on climate change, related energy policy and how governments should respond: Sir David King saw this as the most important issue facing government. Sir David presented the ninth Zuckerman lecture in October 2002, hosted by the Foundation, on the subject of climate change – the printed lecture was reprinted many times and it was pleasing to see a pile of them in the corner of Sir David's office to give away to his visitors.

In November 2005 the Foundation brought the Hon James Connaughton, Chairman of the Council of Environmental Quality and the senior environmental adviser to the US President, to London for a debate with Sir David on the respective US and UK positions on climate change. Around the debate, two days of visits were arranged for Mr Connaughton – these proved to be very useful and influenced the debate at the Montreal Conference of the Parties held soon after the debate. In November 2006 the Foundation was fortunate to persuade Lord Stern to present his report on the economics of climate change.

Lord Philips of Worth Matravers spoke about the key recommendations of the inquiry he chaired into the BSE outbreak – this happened to coincide with the start of the 2001 Foot and Mouth Disease outbreak. At the meeting Sir David King instead of discussing BSE gave a fascinating description of the speed at which new cases of FMD were being identified and the arguments for culling of cattle in neighbouring farms to stem the growth of the epidemic.

Lord Sainsbury of Turville has been a regular speaker as science minister and, in November, outlined the results of his review of science and innovation in Government, *The Race to the Top*. Representatives of the Government departments most involved with funding science and innovation – particularly Sir Keith O'Nions of DIUS and John Kingman of the Treasury – have also contributed to the Foundation's meetings.

From time to time meetings have had an international dimension. Professor Silas Lwakabamba enthralled the audience in May 2004 with his description of setting up from nothing the Kigali Institute of Science, Technology and Management in Rwanda. The Rt Hon Hilary Benn, then Secretary of State for International Development, also spoke at the meeting. And in March 2007 Sir Gordon Conway, CSA at the Department for International Development, and Aleke Banda, a former Finance Minister from Malawi, spoke about the stark choices faced by developing countries.

Jointly with The Royal Society of Edinburgh the Foundation organises a meeting each year in Edinburgh and recently one in Glasgow. These meetings are often preceded by a workshop. Topics have included the Common Fisheries Policy and its implications for Scotland, the importance of research skills for the Scottish economy and the issues of drugs, alcohol and health (held in Glasgow). In 2001, a meeting was organised at Cambridge on the management of risk, as part of a short programme at the Isaac Newton Institute for Mathematical Sciences.

International cooperation

Finally I will mention one other event which is close to my interests after my many years working in the oil industry for BP. In October 2005 the Foundation organised a conference for 300 participants on cooperation between the UK and Norwegian oil and gas industries. The conference was opened by the King of Norway, HM King Harald V, and His Royal Highness Prince Philip the Duke of Edinburgh. It was closed by the energy ministers of the UK and Norway.

Reports of all the Foundation events are recorded on our website, www.foundation.org.uk. I am very grateful to our note takers for succinct, impartial record notes of our meetings – Sir Geoffrey Chipperfield, Sir Crispin Tickell, Sir David Omand and Jeff Gill. Papers from the speakers are published in the Foundation's journal, *FST Journal*, edited by Sir John Maddox and ably pulled together by the Production Editor Simon Napper. The journal is published on the website and sent to 1,500 contacts in Parliament, Whitehall, the Research Councils, devolved administrations, business and academic leaders.

I must not finish without thanking Keith Lawrey for organising events and publishing a newsletter for over 150 learned and professional societies that are members of the Foundation.

As Chief Executive, I have benefited greatly from the efforts of my predecessor, David Hall OBE, to establish the dinner/discussions on a firm footing and the Foundation on a sound financial base.

I am very grateful for the support of the Council of the Foundation, particularly the Foundation Chairman, the Earl of Selborne KBE FRS, and President, the Rt Hon the Lord Jenkin of Roding, and to the many members, sponsors and grant-giving bodies who have supported the Foundation financially. ❐

Creating the conditions for the UK to compete in the global economy was the theme of the Sainsbury Review of Government science and innovation policies. The final report was discussed at a meeting of the Foundation on 14 November 2007.

The Race to the Top – the UK can be a winner

David Sainsbury

When Gordon Brown asked me to review the Government's science and innovation policies it was in the context of competition from low-cost, emerging economies. He is very concerned – and I think rightly – that if we do not have a clear view on how to compete with countries like China (where wages are just 5 per cent of those in the UK) then we are in danger of seeing a rising tide of protectionism.

We say very simply in the report that company strategies based solely on low cost will fail, producing a race to the bottom with emerging economies. Instead, we need to create the conditions for industry to restructure into high-value goods and services and so compete with emerging economies in a race to the top. The economy has already begun the move into high-tech manufacturing and knowledge-intensive services. In 1993, 36.4 per cent of the added value in the economy was in high-tech manufacturing and knowledge services. By 2002 that figure had gone up to 40.5 per cent.

The *Race to the Top* requires Government to refocus support for industry on knowledge generation, innovation, education, training and infrastructure development – technological infrastructure development particularly – and to remove barriers to innovation and growth.

It is important that we understand this is a major challenge to our economy – we need to prioritise expenditure on policies which enable us to create conditions for industry to move up the value chain.

The knowledge economy

Let me highlight a few elements of the review. First, we continue to have a remarkable record of discovery and this is a major asset in the global knowledge economy. In 2005, the UK was ranked second to the USA with a 9 per cent share of world scientific papers and 13 per cent of citations. We also produce 13 per cent of the most-cited one per cent of papers and we have a very consistent performance ranking – second in the world in seven of the 10 disciplines.

The Lord Sainsbury of Turville, Chair of the Sainsbury Review, joined J Sainsbury plc in 1963 and served as Finance Director, Deputy Chairman and Chairman before he left the company and was appointed Minister of Science and Innovation at the DTI. He served in this post from July 1998 until November 2006 – one of the longest serving science ministers.

Next, our innovation performance is better than commonly thought. The two measures which are commonly used are R&D as a percentage of GDP and the number of patents. Superficially, our performance looks rather unimpressive but when you investigate those figures a different picture emerges. We have a number of industries which are extraordinarily successful internationally, but which undertake very little R&D: an obvious example is financial services which plays a big part in our economy. We have one or two – oil and gas for example – where a great deal of R&D is carried out, but as a percentage of revenue this is actually very small. We also have a number of successful industries under foreign ownership and the R&D is not done within the UK. Once those adjustments are made, it is clear that the relevant industries are performing well both on patents and the amount of R&D.

In this context there has been a remarkable change over the last 15 years in knowledge transfer from our universities. In the last 18 months there have been six spin-outs which have been acquired for £1.8 billion. So the old story that our universities are ivory towers without knowledge transfer is simply no longer true. We are also seeing the growth of high-tech business clusters around our world-class research universities.

Capital investment

The review also looks at the way venture capital is invested. Specifically, we commissioned research that compared spin-off companies from universities in the UK against the record of universities in the USA, in terms of the amount of venture capital they were attracting. Stanford is probably the best example in America, while Wisconsin and Washington come about 15th and 16th, so we compared British universities against these examples. There are probably eight or nine British universities that come within those limits. The overall conclusion of this piece of research was that UK universities are now producing spin-off companies of an equivalent number and quality to the USA's top institutions.

There is also a very good correlation between money invested in or around universities and the RAE scores of those universities. So the answer to the question 'what value do we get from the basic research we do?' is that 'this is what companies want, and that's why they locate around our world-class research universities'. That should not be a surprise. If you look at the universities in America that have high-tech clusters around them, they are places like MIT, Berkeley and Stanford – all world-class research universities.

Then there is the balance between the basic and applied research supported by Government. Ministers are continually encouraged to focus on one or the other. In fact, we need both. It is very important to support world class research in our universities, but at the same time to support the work of the Technology Strategy Board (TSB) in supporting collaborative, user-driven R&D.

Now if there are 100, or 110, universities they should not all be expected to do the same thing. What one wants is a diversity of excellence and there are important missions both for research

universities and what we call, not very elegantly but I think rightly, 'business-facing' universities.

Recommendations

Given that background, we made a number of recommendations which can be grouped under five headings.

The first is to give a leadership role to the TSB. It has already been very successful and is now an executive, non-departmental public body which can recruit widely and not just from the civil service base. It has a very good chairman under Graham Spittle of IBM and has just recruited a chief executive, Iain Gray, from Airbus UK. I think it can perform a very good role in providing technological leadership, particularly in the field of user-driven research. That is necessary because inevitably different parts of Government get involved in these issues and there is a real risk of them all going over the same ground. We can coordinate the effort better and industry can relate to one body.

Second, we want to build on our success in knowledge transfer and there are four areas where we can take the agenda forward. We want to see the Higher Education Innovation Fund awards moved to a formulaic basis and the extra money allocated should be directed to the business-facing universities. While competitions may focus minds on what people really want to do with this money (as opposed to just doing more of the same), it is not a good strategy for the long term as it provides no security for those undertaking the work. We also think that HEIF can work more closely with SMEs. We want clearer targets for knowledge transfer from the Research Councils – not moving them away from basic research, but making certain that related commercial opportunities are pursued. We want to double the number of the knowledge transfer partnerships (KTPs) which provide a very good mechanism for bringing universities and small businesses together. We do not, however, want to see a large number of new initiatives; instead we want more resources for those that already exist.

We think there is also an opportunity to achieve knowledge transfer by involving Further Education colleges. This would be very good for raising the level of teaching in these places, as well as providing a convenient way for small businesses to enter knowledge transfer networks.

Enhancing teaching

Third, there should be a major campaign to enhance the teaching of science and technology in schools and universities. One of the most difficult challenges we encountered was in trying to identify how science and technology are actually being taught in schools (and indeed in universities) because there is a great deal of myth circulating about it. Figures are inconsistent and it has taken a long time to develop a coherent picture. For example, there was an appalling drop in the numbers taking mathematics in 2003, but this was due to the introduction of an AS level which was far too long and which could not possibly be covered by the students. The situation has been corrected and numbers are rising again. There is a danger that if anything like this goes wrong people say 'well young people do not like doing difficult things and working hard' but it had nothing to do with that.

A few years ago, the numbers studying further maths were going down steadily. Once again, it was claimed that this was because young people did not like working hard on difficult subjects. The actual reason was that it was not offered in many schools because there were not enough people capable of teaching the subject. An online scheme, with mentoring, was introduced and the numbers started to improve rapidly. Not only have we now recovered lost ground, we have progressed further.

Currently, a major problem area is physics where we have seen a 20 year decline in the number of people taking A-levels. When you look back over those 20 years it is obvious what the problem was – the introduction of 'double science' which almost squeezed physics out of the curriculum. In many cases this subject was taught by someone not qualified in physics and it is very difficult to enthuse students without a good teacher. The answer is that we now need many more qualified physics teachers. We also want to see an increase in the number of young people studying triple science, because that seems very important. In addition, we have to improve curriculum development for teachers.

Now at university the numbers studying science and technology are going up as a percentage of the total. That conceals a major problem. In a number of subjects – chemistry, engineering and technology – there has been a fall while the very large increase has come in three areas: forensic science, sports science and psychology. This shows a serious mismatch between what young people are studying and their future job prospects. The answer must be better careers advice. There has been a lamentable decline in careers advice in schools and we need to make that right, particularly in professional or vocational areas. The Higher Education Funding Council for England (HEFCE) should examine – and report annually on – what is actually happening in universities, what industry believes the problems to be, integrating that with information about where graduates go and what salaries they command.

The role of Government

Fourth, there is the role of Government departments. We want to see innovation embedded in departmental strategic objectives. We want to see the Department of Innovation Universities and Skills (DIUS) produce an annual report highlighting exactly what is happening across Government in the area of innovation. In this agenda, procurement is extremely important. The problem lies not in deciding what needs to be done, but rather in getting departments to undertake a process of business transformation so that it is carried through properly. That I think is now taking place.

We also want to see the Small Business Research Initiative reformed and managed by the TSB. We have already tried to introduce this programme twice, each time without success. We now understand why it has not succeeded and hope to remedy this by giving the TSB administrative responsibility for it.

The final point concerns regulatory bodies. Take the Office of Gas and Electricity Markets (OFGEM) for example and look at research on the National Grid: we actually reached a point where no research was being done. At that point, they recognised there was a problem and research has now gone up to £6 million. But there is a huge investment programme in the Grid and a great deal of technical change to deal with things like renewable energy. I just cannot believe that £6 million is the right figure: we need to include innovation in the terms of reference of these bodies so that they do not focus solely on reducing short-term consumer prices.

We also believe that the RDAs can do more on science and innovation and in particular should focus on knowledge transfer partnerships, high-technology clusters round world-class research universities and the nationally specified Proof of Concept scheme.

A record of good progress

The UK has made good progress in recent years in responding to the challenge of globalisation and upgrading its industry. But China and India will not be content to remain low-cost manufacturers for the world: the reason being simply that there is not much money to be made. They are determined to become high-tech, value-added manufacturers. Yet it is realistic for the UK to aspire to be a global leader in science and innovation, and we can be one of the winners in the race to the top – but we have to move very fast. ❐

www.hm-treasury.gov.uk/media/5/E/sainsbury_review051007.pdf

Implementing the recommendations – the Government's role

Keith O'Nions

The essence of this report goes well beyond simply the R&D and technology contributions to innovation. It calls for a more coherent deployment of assets. We are now beyond the Comprehensive Spending Review (CSR), in which we achieved the highest ever level of investment in science in real-terms and I do not doubt that the *Race to the Top* – the Sainsbury Review – helped greatly in arriving at that settlement.

While some of its recommendations are not primarily dependent on budget increases (these are cultural changes and concern the way in which we go about our business) many are. The outline increases to the Research Councils published in October gave an overall 2.7 per cent real-term increase per year. That is about 5.5 per cent in cash terms, year-on-year. Looking in more detail, the Medical Research Council has a 30 per cent increase over the CSR period. This is due to the adoption of the Cooksey Review recommendations for increased funding of translational research. There are also very significant increases in the English national NHS budget for the National Institute for Health Research (NIHR). Together, these increases will fund a higher level of translation. However, the basic research in the MRC is fully protected. This is an exceedingly important message: this is an increase, pro-rata, in basic research plus a significant increase for translation.

Sir Keith O'Nions FRS was Director General, Science and Innovation, at the Department for Innovation, Universities and Skills (DIUS) until March 2008. Sir Keith has held academic positions in the Universities of Oxford, Columbia and Cambridge. He was Chief Scientific Adviser to the Ministry of Defence from January 2000 to July 2004.

A significant part of these very substantial increases for Research Councils goes into full economic costing, i.e. maintaining the sustainability of universities. Next year about £180 million extra goes from these budgets into universities. By the end of the CSR it will be a further £300 million. Sustainability has been a pillar of Government policy.

Achieving a balance

The Technology Strategy Board is an extremely important part of striking the balance between user-defined research – or applied research if you like – and the more university-based basic research. For this strategy to succeed, and if the Race to the Top recommendations in this area were going to have effect, it was necessary to get significantly more money to the TSB and that has happened. £180 million co-invested from RDAs, £120 million co-invested from the Research Councils and a substantial increase in the TSB budget are very welcome.

Many of the recommendations in Race to the Top are budget-dependent and relatively straightforward to implement. We are making a third attempt to establish the SBRI (Small Business Research Initiative). This involves the adoption of a US model which has been running for 20 years. David Sainsbury has now set targets for Government but these will not be achieved unless there is ongoing persuasion through the TSB and I suspect there will need to be some ministerial support as well. But it is the right thing to do – there is a big prize to be won. Boosting the supply of people with STEM-skills (Science, Technology, Engineering and Mathematics) will not happen without continuous attention and coercion: it is not just a matter of money.

Council	Comprehensive Spending Review 2007 increase (%)
Arts and Humanities Research Council (AHRC)	12
Biotechnology and Biological Sciences Research Council (BBSRC)	22
Economic and Social Research Council (ESRC)	19
Engineering and Physical Sciences Research Council (EPSRC)	19
Medical Research Council (MRC)	30
Natural Environment Research Council (NERC)	17
Science and Technology Facilities Council (STFC)	14
Total Science Budget	17.4

Increase in allocations to Research Councils

Year on year increase in science spending by Government.

DIUS

While the Review was being carried out, the Office of Science and Innovation was part of DTI. We now have a Department where higher education, post-18 skills and science innovation have been brought together. Of £17 billion, science innovation is actually the smallest component of that Department's budget. Within a year, DIUS will produce a report on the implementation of Sainsbury. It will also look at its own strategic objectives and it has already started work on that.

Whether this will result in new policy remains to be seen, but in a Department where skills, higher education, science and innovation are drawn together the question inevitably arises as to whether the present set of policies around skills, training and education offer the best support to innovation. Also, is there a role for Government in supporting innovation management? Many people think process-driven innovation is not a place where governments should get involved, but perhaps there are areas where it should. I do not have any immediate answer: the relevant discussions will need to take place. ❐

A leadership role for the universities

Eric Thomas

The universities agree completely with *Race to the Top* – this is the way forward for the UK economy in general and the knowledge economy in particular. We accept everything in the report and the major recommendations. We agree with the new role for TSB; we are quite clear on our support for knowledge transfer and in enhancing the teaching of science and technology.

The university sector itself has changed dramatically in recent years, not only in terms of performance indicators like spin-outs, licensing, etc – the culture has also changed completely. Academics embrace the concept of knowledge-transfer, they recognise it as a central plank of their activity, they want to do it. We are very pleased with the report's recognition that universities are at the centre of this activity – and not all countries, not even all first-world countries, would articulate that so clearly.

'Business-facing'

We are comfortable with the descriptions 'research-intensive' and 'business-facing' and the recognition that they are not mutually exclusive. It is really important to have a positive label for universities that are not research-intensive, one which articulates what they do and what they give to their locality and their sub-region.

We believe that SMEs represent a real challenge in terms of integration within the university's mission. There are some good examples of work though – the universities in Bristol have set up the Bristol Enterprise Network precisely to draw SMEs to the university sector. Its purpose is to provide easy access for high-tech SMEs to the knowledge, expertise, experience and equipment available within the partner organisations in the network, including the University of Bristol. So it is not just concerned with SME links to the university, it is also about links between SMEs. The network provides information and it organises 'speed dating'. Participants spend two minutes with each other, asking each other what they do. We also have evenings in the University where we show SMEs what we do and we give them training and development opportunities.

Professor Eric Thomas FMedSci is Vice-Chancellor of Bristol University. He trained as an obstetrician and gynaecologist and worked as a consultant gynaecologist from 1987 to 2001. Professor Thomas is currently a member of the Board of the South-West Regional Development Agency. He is Chair of the Research Policy Committee of Universities UK and a member of its Board.

Universities must provide more training and education in enterprise, entrepreneurship and innovation in their undergraduate and postgraduate curricula. We should have credit-bearing modules in this area for undergraduates (some engineering faculties already do) and we need to produce graduates who embrace and understand enterprise and innovation.

We need to offer support to high-tech clusters around research-intensive universities. A good example is the cluster of photonics companies around Southampton: photonics is one of Southampton University's major strengths.

On the international stage, we can add capacity to innovation by working with global partners. Today there are problems that even individual countries cannot tackle on their own – they need the resources of others. There are, of course, intellectual property complications of working across countries.

Universities should work on innovation in the public sector as well as the private. The classic partner here is the NHS where there is incredible innovation – orthopaedic surgeons developing new tools, new materials, new equipment, for example – it is not just drugs. Yet we are not yet exploiting this fully, although I know the NHS is very focussed on encouraging innovation.

Secondary and further education

We are very supportive of extending this activity into further education. FE is the most under-valued part of our educational firmament and anything we can do to make it more valued and to stimulate it is very important.

I would like to make a couple of observations about improving teaching in science and technology. I think diplomas offer a real opportunity to re-engineer the 14-to-19 educational experience. Universities should embrace diplomas because they can actually make a real difference to the curriculum. They are not about dumbing-down, diplomas are an opportunity.

For the first time this year we have had to change our chemistry and physics departments into 'selecting' departments, rather than 'recruiting' departments. We had to take an additional 60 physics students because the department over-offered. The message that science is 'good to do' is getting out. However, we have invested about £130 million in this area over 10 years. We now have excellent teaching laboratories for physics and when youngsters see them, they want to come to Bristol. Now the number of universities that can actually make that investment is limited. Is a concentration of facilities inevitable in order to allow that investment to take place?

The RDA view

There are Regional Development Agencies in this country that work very closely with Higher Education. The highest investment priority for the South West Regional Development Agency lies there. There are science parks in Plymouth, in Exeter and one in north Bristol – this has involved an investment of £30 million.

With their budgets in real terms decreasing, though, RDAs will not have the capacity to fulfil this task. While RDAs understand its importance, they are up against a significant budgetary constraint.

The universities will provide leadership – that is the job of vice-chancellors. But the Vice-Chancellor of Cambridge, Alison Richard, referred to the term 'innovation ecosystem' used in this report. She reminds us that ecosystems are diverse, complex and non-linear: this can result in fairly chaotic outcomes from what appear to be sensible interventions. We need leadership, but we need to take care that the flowers bloom as well as providing a direction for innovation. ❐

Speaking in a language that business can understand

John Cridland

The business community believes the Sainsbury Report sets out the current state of innovation in the UK economy.

Alison Richard was right that the choice of the phrase 'innovation ecosystem' in the report is significant. Her comment, on the difference between something dynamic and varied and something orderly and linear, is very relevant to the CBI, because the innovation of our member organisations involves design, research, effective marketing, consumer insight, software development and application prototypes, testing and refinement. It is very varied and diverse and by no means linear.

This notion of an innovation ecosystem takes us into a new realm. So does the emphasis in the report on service sector innovation. If the service sector accounts for 70 per cent of the UK economy, we need a language that is meaningful to these businesses and we need metrics which capture what they do. We have not had that in the past.

The real issue

For too long ministers, politicians and other commentators, both here and across the European Union, have said that we need to spend more on innovation. Now, we may well need to spend more, but in a targeted fashion. The R&D scoreboard shows that for our best-performing R&D companies, the growth in spending is at least as good – and in many cases outpaces – the best of our international competitors.

John Cridland CBE is Deputy Director-General of the Confederation of British Industry (CBI). He joined the CBI in 1982. He has been Director of Environmental Affairs and of Human Resources Policy. John Cridland spent 10 years on the Low Pay Commission and the ACAS Council, and was also a member of the Commission on Environmental Markets and Economic Performance. He is a member of the National Learning and Skills Council. He was awarded the CBE in 2006.

The Technology Strategy Board should now provide, in our view, the critical accelerant for technology development. We have always envisaged a TSB with a mission somewhat similar to the DARPA (Defense Advanced Research Projects Agency) approach in the USA, seeing this as a model in terms of focus, dynamism and engagement with business.

We believe that the TSB will eventually need around £600 million per year of funding, rather than a third of a billion as at present, if it is both to sustain collaborative research projects and enable the pilot innovation platforms to reach critical mass.

Science teaching

I think everything that David Sainsbury had to say about science teaching and skills has struck chords with the business community. We have made ourselves unpopular in some quarters by emphasising this 'crisis in science'. We do not apologise for calling for greater urgency and the danger is that collectively we will not live up to the level of ambition that David has set out. There is so much that we need to change, and change rapidly, in areas that are not easily susceptible to such change. The problem is – with no disrespect to those in that profession who have a very challenging job – the baseline is in a dire state. We need to sort out careers education and guidance before we can satisfactorily sort out STEM. We also need to make a greater effort to get many of our young people studying triple science because we believe that is where the rot originally set in.

Finally, notwithstanding the helpful trend in broader science studies in universities, there are still issues to be addressed. We may need to look at some new and innovative approaches to supporting STEM undergraduates. In particular we have suggested that bursaries will be needed. ❐

Engineering will play a major part in tackling climate change. A dinner/discussion at the Royal Society on 16 October 2007 looked at some of the key issues.

Engineering a response to climate change

John Browne and Scott Steedman

Science has done much to establish the causes and consequences of climate change. Thanks to the IPCC and many other scientific organisations, our levels of confidence in the links between anthropogenic emissions, the concentration of greenhouse gases in the atmosphere and the increase in global temperatures are much higher than 10 years ago.

We now have 'virtual certainty' that past greenhouse gas emissions will increase the global mean temperature over the next few decades and also that continued greenhouse gas emissions – at or above current rates – are very likely to produce further significant warming and induce other changes in the global climate system during the 21st century. We also know it is 'very likely' that extreme weather events, such as heatwaves and heavy rainfall, will become more frequent. There is more to do on the scientific front, but there is a broad scientific acceptance that the risks to our planet – and to human activity – are considerable.

Lord Browne of Madingley FRS PREng is President of the Royal Academy of Engineering. He was group chief executive of BP from 1995 to 2007. Dr Scott Steedman FREng FICE, who delivered the address, is a Vice President of The Royal Academy of Engineering, a President-elect of the Institution of Civil Engineers and Director of Group Strategy at High-Point Rendel.

Practical options

Scientists and engineers are presenting policymakers with real, practical options for reducing greenhouse gas emissions. For example, Bob Socolow at Princeton has suggested 15 practical options that would each reduce carbon emissions by one billion tonnes each. The most important of these would reduce carbon emissions sufficiently to stabilise atmospheric CO_2 at safe levels by 2050, compared with 'business-as-usual' projections:

- increasing the fuel economy of two billion cars from an average of 30 to 60 miles per gallon;
- replacing 1400 coal-fired power stations with natural gas fuelled ones;
- replacing 700GW of coal power with nuclear fission (twice the current capacity);
- adding two million, 1MW wind turbines (50 times the present capacity);
- installing 700 times the current global capacity of solar panels; or
- creating 3500 'Sleipners' for geological disposal of CO_2. (Sleipner is the Statoil gas field in the North Sea where about 2,800 tonnes of carbon dioxide are separated daily from the gas production and then injected into the saline sandstone aquifer formation, rather than released to the air.)

Among the other possibilities, carbon capture and storage (CCS) is one of the more exciting emerging technologies. The concept is that we can capture 90 per cent of the emissions from coal- or gas-fired power plants and store them safely and permanently underground. CCS is expensive, but we may have to do it.

Biofuels is another technology that we urgently need if we are to improve global energy security. The switch from food to fuel – using first generation biofuels made from food crops – has led to price rises of staple crops and public concern over food security. Research on the next generation is focused on extracting fuel from discarded plant waste matter, such as corn husks, straw, prairie or 'switch' grass, and by developing technologies for breaking down lignocellulose, the 'woody' component of the plant cell wall.

The cost of conversion is the principal barrier. Breeding plants to increase their biomass is one possible approach. Another is to genetically engineer plants to make it easier to break down the lignin and cellulose.

Demand side measures

Another area I would highlight is that of demand reduction. By any statistic, the opportunities to reduce emissions within the built environment are staggering. BRE estimate that about 40 per cent of all greenhouse gas emissions are associated with energy use in buildings. Typically, about 80 per cent arise from building use and 20 per cent from its construction and demolition.

About 60 per cent of buildings-related emissions are from housing – largely for heating. Important though it is to develop standards for new build, improving the insulation of our existing building stock must be a top priority.

Many of the opportunities in demand reduction are cost-positive. The challenge is to change a culture that does not encourage people to adopt an integrated approach to energy management. Real-time pricing would give people feedback on their energy use. Allowing them to generate electricity and put it back into the grid would be a paradigm shift.

Overall, scientists and engineers are playing their proper roles in society in relation to climate change. They are helping to advance our understanding of climate change and are offering society practical choices for reducing emissions.

Business is also playing its part. The overwhelming majority of business opinion has accepted that the climate change threat is real, that immediate action is necessary and that the costs of taking it are manageable. Ten years ago only a handful of companies – including BP – belonged in that camp.

If you look through any newspaper or business magazine, you will find innumerable companies describing what they are doing on environmental issues in general and climate change in particular. This is not just an issue of branding or public relations – though it is fascinating and indeed very encouraging that so many companies feel they should be advertising in this way.

Of course, the most important actor is Government. Only Government can create and police the framework within which genuine progress can be made. It establishes the critical path in society's response to climate change.

The international dimension

There are almost as many climate change policy recommendations as there are policy makers. But one of the biggest steps forward would be to put in place a robust international climate policy framework.

The most effective solution is to work on the largest possible scale, targeting

reductions (and the resources required to achieve them) on the places where the cost of abatement is lowest and the impact is highest. Targeting resources where they have the largest impact is what a business plan is all about – and that is what we need now, a global business plan for the transition to a lower carbon future.

To deliver this, the international community should create an International Climate Agency, with responsibility to:

- establish a long term greenhouse gas stabilisation goal;
- set fair and equitable emissions targets that lead to this goal;
- issue emissions allowances in line with those targets;
- design new ways to encourage clean, low carbon development in the emerging market economies, where the largest increase in emissions will occur;
- encourage global technology transfer;
- undertake the monitoring and verification that is necessary to build trust and credibility in any institution.

This ambitious proposal would require governments to rediscover the sense of global collective endeavour that secured peace and prosperity after the Second World War. Given the remarkable rise of public concern about climate change in recent years, concerted global action of this kind is increasingly realistic.

The stark fact, recognised with increasing alarm by publics around the world, is that time is running out. Emissions are growing and the pace of that growth is accelerating. A new global 'business plan' for climate change – monitored and enforced by an international climate agency – would be the appropriate international response.

discussion

The role of engineers. Some speakers argued that it is not good enough for engineers and scientists to tell the rest how, for example, to insulate our houses or reduce vehicle traffic and then for them to suggest that it is up to Government to make decisions. The engineering profession, it was suggested, should not simply inform ministers but should have a firm policy line and they should then put pressure on Government to encourage its adoption. Some speakers also suggested engineers should work more forcefully to educate the public.

Rising to the challenge

When rising to the challenge of climate change, national governments will take existing political cultures and regulatory structures into account when making policy. However, certain rules of thumb should apply. Policymakers should avoid 'picking winners' and should instead provide incentives to as broad a suite of low-carbon technologies as possible.

Wherever possible, they should also use market mechanisms to ensure resources are directed to areas where the biggest impact can be made at the lowest cost.

Policymakers should also recognise that carbon pricing is not a 'silver bullet'. We will need transitional incentives, ranging from tax incentives and quotas to price support mechanisms that accelerate the deployment and diffusion of less mature low-carbon technologies.

A particularly tough policy challenge is to provide incentives for technology demonstration projects. Demonstrating a new technology is costly and additional incentives are often needed to persuade business to undertake a first project. The problem is that a single carbon capture or IGCC project is huge and can swallow billions of dollars of investment capital. This means that the Government support required is also large, perhaps hundreds of millions of dollars at a time. Steering such sums through the political system quickly is not easy. This will require a new approach to policymaking as well as real political leadership.

Finally, national governments must also remove policy barriers – some unseen – that prevent low-carbon technologies from reaching the market. Such barriers include daily (as opposed to 'time-of-use') pricing of retail electricity, since this effectively discriminates against solar power. Other obstacles include the absence of a legal framework governing carbon capture and storage in most parts of the world, and the cumbersome planning rules that slow down the development of onshore and offshore wind projects. ❐

Technologies to reduce emissions

John Loughhead

The UK has ambitious targets to reduce its emissions of carbon dioxide by 20 per cent by 2020. This has profound implications for the way we use energy, the source of that CO_2.

By any estimates fossil fuels will remain the dominant source of energy, certainly to 2050. So we need 'clean' fossil fuels if we are to meet the UK's targets for CO_2 emissions. This means that we need better technologies for electricity generation. For example, advanced steam-turbine cycles would burn fuel at higher temperatures. The limitation is the combustion process, our ability to manage it and, more importantly, our ability to master the materials science that is central to turbines. If we look at the technology of gas turbines, the modest improvements that we have seen over the past 10 years have been achieved via enormous development costs.

Carbon capture and storage

Carbon capture and storage (CCS) is another technology that we wish to perfect. The UK is developing a demonstration that, hopefully, will get us from the talking stage to the doing stage. The existing experiment in the Sleipner Field in the North Sea is an example of carbon capture in action. It puts back into the Field CO_2 generated by burning the methane extracted from it. If we wish to reduce our emissions by 20 per cent by 2020, and then 60 per cent by 2050, we need to bring into service three such sites every year starting now. This is a phenomenal undertaking.

We may be able to use fossil fuels differently. For example, the underground gasification project at Chinchilla in Australia extracts coal as a synthetic gas which is then burned in a turbine. The British Geological Survey has shown that the UK has substantial coal reserves that

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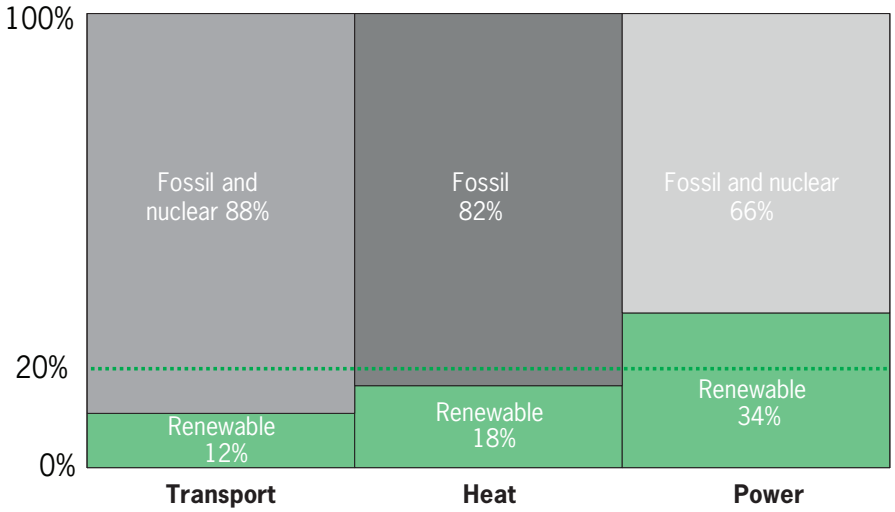


Figure 1. Achieving an overall 20 per cent of renewable energy in three sectors.

are suitable for gasification.

Fuel cells can be used for stationary power and for transport. The European Commission has announced a pan-European initiative that will put around £50 million a year into fuel cell technology in order to take it to the deployment stage.

Renewables

We need to look at a range of other possibilities if we are to obtain 20 per cent of our energy from renewable sources by 2020 – the EU target. There is no real chance of achieving that target for transport. So, if we are to reach the overall target, more than a third of our electricity has to come from renewable sources. The balance would almost certainly come from fossil and nuclear fuels (Figure 1).

Renewables are a tremendous resource if only we can harness them. The daily average level of solar radiation arriving in the UK is about 120 watts per square metre. But that is very diffuse. If the problem is one of concentration, what might we do? One answer is 'build our own Sun'. That is something that is now being pursued energetically at an international scale through the ITER fusion project. But this will take many years. We do not have time to wait and see if fusion will work.

One existing technology, wind power, is extremely important in the UK context. Installed capacity is just under 2GW, just one per cent of the UK's electricity consumption. To produce 20 per cent of our electricity from wind turbines by 2020, we need to install an extra 28GW. However, if electricity generation has to take a bigger burden (in order to reach an overall energy target of 20 per cent) then we need about twice that extra wind capacity, about 57GW. Now global installed capacity is around 74GW, so, in 13 years we will have to install three quarters of what the world has cumulatively done to date. That is probably impossible.

Fortunately, the UK has other options, such as wave energy. When I was an equipment manufacturer, we used to love wave energy projects: when the project team collected the first order we knew that about a month later they would be back for a second – because the first would have sunk!

That is because this is probably the harshest environment for which to engineer products. It is much harder than space, for example. These things have to endure enormous forces and they have to withstand corrosion. They are away from regular maintenance, so they have to survive on their own. That is not an impossible task but we should not underestimate it. While we may make progress by 2020, we will not have got very far.

Tidal power is another possibility. It is regular and it is reliable. We should certainly pursue it, but there remains a lot of engineering and technology to do.

Biofuels

Biofuels will also be important. The current target is for five per cent of the UK's transport fuel to come from renewable resources. If we take all of the arable land that is not used to produce food – it is about 14 per cent of the total, about 0.8 million hectares – we can produce about 2.8 per cent of our road transport fuel. If we look at what we might be able to do by about 2020, with improvements in agriculture and other areas, we might get up to 3.8 per cent and by 2030 5.6 per cent. So we would have reached our target but 10 years too late!

We also need to ask ourselves how we could save energy. Energy conservation and efficiency are more important than finding clever new ways of producing it. We have a commitment to reduce demand by 20 per cent by 2020. I believe that we will also be moving to a much more highly distributed generation system – not exclusively, but we will start to find ways that give us savings. More important than everything else, we need to work out how to become a lower energy society. ❐

The risk to the insurance industry

Rolf Tolle

Climate change will affect many parts of the insurance business. We can expect larger claims on policies that pay out when property is damaged. Wind damage is likely to increase as storms become more powerful and larger ones more frequent. The US hurricane season may start earlier and end later. Severe weather may affect new locations: a tropical cyclone hit Portugal in 2005, for example.

Other parts of the insurance market could also feel the effects of climate change: for example, the policies which corporations take out to cover litigation costs. Legal firms warn that class actions related to climate change are becoming more sophisticated. Large emitters of greenhouse gases, or those whose products lead to emissions, could be sued and should these actions be successful this could lead to claims.

Directors may be sued for not foreseeing the adverse effects that climate change may have on their businesses. If it is deemed that they should have done so, then such litigation may succeed and result in insurance claims.

Rolf Tolle is Franchise Performance Director at Lloyd's of London. Previously, he was Chief Underwriting Officer and a Board Member of Faraday Group, the London based insurance operation owned by General Re Corporation. Prior to this, he spent 10 years as Chief Executive Officer of Europa Re, based in Cologne.

discussion

Public opinion. Some questioned whether the public take climate change seriously enough. It does not help if there is no overall vision or sense of urgency, though. Perhaps we should address climate change as if it were a war and take decisions on a war footing. If the Government allows a delay of five years on planning permission for an offshore wind farm, 15 years to build the Thames barrier, or 10 years for revising building codes, then they demonstrate that they do not appreciate the seriousness of the issue.

Similarly, architects and other engineering professionals may face legal action for not considering climate change in their building designs, for example. Again, if successful, this may lead to claims against professional indemnity policies.

The world economy

The impact of climate change on the world's economy, and its consequent impact on the value of an insurer's financial assets, is less discussed. The value of our assets, and the ability to pay claims might be affected. On the other hand, insurers could consider using creative hedging strategies, such as investing in the construction industry, which tends to perform well after a hurricane.

We have to help governments and policyholders realise that their actions can help to keep property insurable at affordable rates. Clearly, this is where engineers can have a huge influence. They can assist the adaptation to climate change with better flood defences, stronger and more resilient materials, stricter building codes, better drainage – in short, designing buildings and contents flexibly and with the future in mind.

It would, for example, seem sensible to avoid new building work in areas that can expect catastrophic events. If we must build on flood plains, let us build houses in the anticipation of flooding and thereby reduce losses when the inevitable happens and catastrophe strikes.

Managing risk

In the meantime, how does Lloyd's manage the risk? Lloyd's is a marketplace with over 60 competing syndicates. One of our requirements is that each year the market must consider the losses it would face under a number of 'realistic disaster scenarios'. These scenarios are extreme but plausible (they are created in consultation with scientists and other experts). If we look at the changes to the framework over the past couple of years we see that past climate change is having an effect now.

Take our scenarios for Florida hurricanes. In 2005, we asked the market to test an industry loss of US$70 billion; by 2007 we had increased this to US$108 billion. The key point is that the new test is targeted at the same level of likelihood. Our views on extreme events have changed dramatically over a short time period.

The public must also begin to see themselves as risk managers rather than just passing risks to their insurer.

We have guidelines that syndicate losses from these scenarios should not generally exceed certain levels. To comply with these guidelines, the Lloyd's markets have reduced their loss potential over a period, thus reducing the level of risk.

It is also important to realise the impact that demographic and economic trends have on the level of risk. Between 2006 and 2007, we did not change the scenario description at all. We used the same strength, landfall location and track for the storm. Despite this, the expected industry loss for this storm leapt from US$100 billion to US$108 billion. This was due to both demographic effects (more people live in the exposed area) and economic effects (the value of their contents increased over the year).

Policyholders can control these issues. Migration to the coast can stop and the value of exposed contents can be controlled.

It is crucial that insurers are permitted to price freely so that the price reflects the level of risk. If governments seek to insulate the public from these necessary price changes, they will not encourage the correct adaptive behaviours.

Working with others

At Lloyd's, we engage with other businesses, within the financial services industry and beyond. And we can work with and lobby Government for action. For example, Lloyd's was a major contributor to the London Climate Change Partnership's paper, *Climate Change: Business as Usual*, which brought together key stakeholders in the financial services industry and also the Greater London Authority.

For some months, Lloyd's has worked with other reinsurers, insurers, brokers, asset managers, the Association of British Insurers (ABI) and the Prince of Wales's Business and the Environment Programme in order to produce a set of principles on climate change. The Prince of Wales launched these on at the ABI's annual climate change conference in September. The principles cover all aspects of our business, including risk analysis, lobbying, raising customer awareness, asset management, and carbon footprint management. Some 40 signatories have signed up to these principles, and we want the list to grow.

Climate change is a major issue for the insurance industry. There will be many challenges in the future, and risks to our profitability. However, we also have an opportunity to help society to spread and manage risk while remaining profitable.

Ultimately, some risks are not insurable. Therefore, it is crucial that we educate people on how insurance can and cannot help. Partnerships with our policyholders, Government and other industries, including engineers and architects, are vital.

The public must also begin to see themselves as risk managers rather than just passing risks to their insurer. That way we can maintain cover for as long as possible, and that is in everyone's interest. ❐

discussion

The scale of the effort. There was some concern about a lack of understanding of the international effort required to implement some of the measures needed to deal with climate change. Carbon capture and sequestration, for example, is an enormous challenge, and not just technically. For it to be effective, we will have to deploy immense resources and create organisations comparable in size to the existing oil and gas industry. We cannot do that without the presence and power of the major global energy companies.

The seas surrounding the UK hold enormous resources but how well do we understand them? A meeting of the Foundation on 20 November 2007 considered the implications of a Select Committee report on the issue.

How should UK marine science be organised?

Phil Willis

There is a lack of understanding, in policy terms, of the importance of the marine environment for ecosystems, biodiversity, bio-resources and energy as well as climate change. There is a lack of understanding of the potential for the marine environment to be exploited commercially and sensitively, other than for transport, fishing and leisure, and the importance of long-term monitoring is not being adequately addressed. Most importantly, without significant investment, coordination and a coherent vision, UK marine science will inevitably fall behind the major players and the UK's chances of solving crucial problems will be drastically reduced. But apart from that, all is well!

Well, let me take a number of these things in turn.

Phil Willis MP was Chairman of the House of Commons Select Committee on Science and Technology until it was dissolved following the reorganisation of Government departments in 2007. He has now been elected chair of its successor, the House of Commons Select Committee on Innovation, Universities, Science and Skills. This new committee will shadow the work of DIUS but will also undertake some cross-cutting science inquiries.

Investment

The Natural Environment Research Council (NERC) is by far the largest funder for marine science and we fully recognise the pressure on research council budgets and the ever-increasing demands on them. However, despite year-on-year increases between 1985-86 and 1995-96, the budget fell in real terms each year until 2003-4 and has continued to fall since then. Overall expenditure – excepting some response-mode grants – was some £5.4 million less, in cash terms, in 2006-7 than in 2003-4. [NERC later submitted amended figures – see page 15.]

These figures exclude the money for the new RRS *James Cook*, but such first-rate facilities cannot properly be exploited if support is not also increased for the research base behind them.

Resources are also diminishing elsewhere. Other than NERC, the Research Councils spend tiny amounts and we recognise major shortfalls in Defra funding too. There also seem to be a lack of opportunities for cooperation across Government, or with industry, or with the Research Councils, to utilise fully the funds that are available.

So to address these issues we recommended, first of all, a full review of future funding by the successor body to the Inter-Agency Committee on Marine Science and Technology (IACMST). In addition, a review by Defra and NERC of mechanisms for improving the relationship between the marine centres and the fishing laboratories, a request that RCUK should monitor joint applications to councils to encourage and support interdisciplinary bids for marine science and an overall increase in funding to meet existing as well as new developments. Quite frankly, without additional funding we will continue to see marine science decline.

Coordination

Now I come to coordination. This was by far the most depressing and disappointing aspect of our enquiry. Despite the clear findings of the Lords Committee in 1986 that there should be a coordinating body comprising all interests including the public and private sectors as well as the universities, instead the more narrowly-focussed and under-resourced Inter-Agency Committee for Marine Science and Technology was set up, bringing together just the Government departments and the Research Councils. The influence of the IACMST can best be judged by the fact that no-one within Government who the Committee spoke to appeared to know who it reported to.

This is not a firm basis upon which to build the new organisation so clearly necessary to coordinate marine science in the UK. What is needed is a body with real clout, at the heart of Government, but involving all sectors with an interest in the sea. It should not second-guess the work of NERC, for example, but it should ensure that marine science in the UK is properly coordinated and resourced. We, therefore, recommended the establishment of a marine agency, reporting to Defra, with executive powers and a budget to oversee operational observations. The agency should bring together all public funders of marine science and other stakeholders such as universities and the users of marine science.

Clearly, the agency would have to respect the structures of the devolved governments which have some very strong relationships with their own marine organisations, in particular, the Scottish Fisheries Laboratory. We would also like to see the new agency be a partner of the British National Space Centre, as there is clearly a case for greater coordination of satellite monitoring of land and oceans.

Crucial to world-class marine science are world-class facilities. We received mixed messages about whether more research vessel capacity was needed although everybody agreed that there was little spare capacity at the moment and that a replacement for the *Discovery* was evermore apparent.

Monitoring

One area of concern was marine monitoring. From previous work we were aware of the importance of maintaining long-term datasets and high-quality monitoring, yet witnesses made it clear that monitoring was the Cinderella of marine science and that funding agencies were much more likely to provide grants for a new database than fund the acquisition of data to put into existing ones.

The critical gap is where a project such as ARGO (an array of 3,000 profiling floats), which is key to providing predictions of climate change, ceases to be a NERC-type research programme and becomes part of operational observations. Essential, but no longer the responsibility of the Research Councils. We want to see better coordination of monitoring activities across the field and have recommended that the new marine agency take responsibility for long-term programmes and be given a budget to fund them. This should

Government responds to Select Committee

The Government responded to the Select Committee's report on 19 December. It says: "The Government has carefully considered the Committee's recommendation to establish a new marine agency, but has decided instead to adopt an alternative approach, that of creating a new committee which will replace IACMST and bring the principal funders together into an effective group." The new committee will be called the Marine Science Coordination Committee (MSCC).

www.parliament.uk/documents/upload/itogovtresp.pdf

include the £22 million deficit in funds necessary to support the UK Marine Monitoring and Assessment Strategy.

The polar regions

The British Antarctic Survey is truly world-class and we recommend that both its mission and funding be fully supported. However, we believe that the whole of marine science would benefit from having a closer relationship with BAS – for example, we felt that having BAS included within the early development of Oceans 2025, as a full partner rather than a latecomer, would add even greater strength to that programme. Of course the real challenge is to increase British efforts in the Arctic, where significant changes which could affect the UK directly are already being detected.

Marine strategy

The trend towards a plan for the oceans is clear in virtually every other major marine science country, from the USA to Japan. There are also on-going negotiations on the European Maritime Strategy Green Paper which goes beyond environmental protection measures to advocate a holistic approach to the oceans. In the UK, ministers talk about the Marine Bill and Defra refers to its paper *Safeguarding our Seas*, but they are much more limited in scope.

We need a comprehensive plan for maritime affairs. Within this we want to see a national strategy for marine science developed in cooperation with the science community and end users. The larger plan should cover the uses of the sea now and in the future. If we are to keep the Government and everyone else focussed on both the strategy and the plan, we believe there should be a Government champion for marine science. There should be a dedicated Minister for Marine Science who should be heeded by Government. And, a volunteer champion, someone who is eminently qualified, someone who is seeking to make a mark in a new post, someone who has the ear of Government would be especially welcome – someone like the new Government Chief Scientific Adviser perhaps!

The UK can, and should, be a world leader in marine science, but we need a radical new direction. There is no escape from the fact that the IACMST is no longer adequate and should be replaced. Simply tinkering with the current structure will not do. We need strong leadership at ministerial level and we need a marine champion – hence our plea to the science community. Above all, we need a comprehensive strategy that recognises our heritage, believes in our future and is prepared to make bold and visionary decisions. ❐

Investigating the Oceans, Commons Science and Technology Select Committee report: **www.publications.parliament.uk/pa/cm200607/cmselect/cmsctech/470/470i.pdf**

Rectifying the mistakes of 20 years ago

Howard Dalton

The best estimates indicate that around five per cent of GDP comes from marine activities. There is no doubt that the marine environment can play a very important role in the economic well-being of the country. Research and development in this area is now much more important than it was 10 years ago. The increasing rate of sea-level rise is an issue that is causing serious concern; indeed the IPCC have referred to this in several of their reports. Renewable energy is an important area: the Prime Minister is now putting his full weight behind that. The 60 per cent carbon reduction that we are aiming for is going to be really tough to achieve but clearly the marine environment is going to play a really important role. There is also the possibility of a new ocean with the Arctic regions thawing and the opening of the North-West Passage: again we need to understand the implications better. We now know that the oceans are becoming more acidic with increased dissolved carbon dioxide and this is causing serious problems, with dramatic effects on biodiversity in particular. Marine research is essential in all these areas.

Professor Sir Howard Dalton FRS died in January 2008. See the obituary on p24. He was Chief Scientific Adviser to the Department of Environment, Food and Rural Affairs from 2002 to 2007 and Chairman of the Inter-Agency Committee on Marine Science and Technology. He was also Professor of Microbiology at the Department of Biological Sciences, University of Warwick. He was elected a Fellow of the Royal Society in 1993 and was awarded the Society's Leeuwenhoek Medal in 2000. He was President of the Society for General Microbiology from 1997 to 2000.

IACMST

The Inter-Agency Committee on Marine Science and Technology (IACMST) has produced a number of important research results, working on a very limited budget with highly talented people. Look for example at the UK contribution to the Global Ocean Observing System. A Strategic Plan was produced in 2006 and recommends a number of important priorities for future UK observing systems, both in the coastal areas and also in the open oceans. It has identified that we need a strong link at national and international level on a whole variety of different initiatives. We need to be involved with the Global Earth Observation System and we need to be involved with the UK Marine Monitoring and Assessment Strategy.

Marine assessments have been very important. The synthesis of data generated and analysed by a whole variety of organisations has been produced in the IACMST report on the *Climate of UK Waters at the*

Expenditure on marine science

Figures from the Natural Environment Research Council (NERC) show that expenditure on marine science has been on an upward trend over the past eight years. These are set out in the Government Response to the House of Commons Innovation, Universities and Skills Committee Inquiry into Investigating the Oceans (Page 8, Table 1), with an explanation of why it believes the figures published in Table 6 of the Committee's original report should be disregarded.

In particular, NERC argues that it was important to include the marine funding elements of interdisciplinary programmes such as the Marine and Freshwater Microbial Biology (M&FMB) programme and the Earth Observation Centres of Excellence. It was also important to separate out NERC's expenditure on large exceptional items such as the new Proudman Oceanographic Laboratory building and the RRS *James Cook*, which had made it hard to see the background trend in research funding.

The re-analysis led to the conclusion that NERC's marine science expenditure increased in cash and in real terms between 1999-00 and 2006-07. Total expenditure (inclusive of blue-skies and exceptional items) was around £15 million more in real terms in 2006-07 than 2001-02, reaching just over £60 million in that year. Marine science will remain a high priority for NERC as it delivers its new five-year science strategy, *Next Generation Science for Planet Earth*.

Millennium. That was updated in 2004 as the *Marine Processes and Climate a* contribution to 'Charting Progress'.

A good example of the value of long-term monitoring has been the Sir Alister Hardy Foundation for Ocean Science (SAHFOS) Continuous Plankton Recorder operation. This is a time series of observations going back to 1946. Executed with relatively simple technology, it has enabled us to understand the changes in the phyto- and zoo- plankton within the open oceans: that has been very important because it helps us understand the food chain. Comparing the plankton change with the total cod biomass, for example, it is clear that the two are following each other almost perfectly. That helps us see what is likely to happen to the fishing industry in the future.

Many of the achievements from IACMST have actually come from our own activities, our bottom-up approach of getting together, deciding what needs to be done and then trying to get on and do it. Largely through funding from NERC, we have actually managed to keep our heads above water and produce a number of important papers as well as providing an environment for individual members to get together.

One of the questions posed is 'why has top-down coordination been so weak?' To answer that, we have to understand exactly how IACMST came to be in the first place.

The origins

"UK marine science is poorly coordinated, fragmented and under-funded," said the House of Lords Science and Technology Committee in the 1980s (it does not seem much different now, and that really is something to worry about). As a result of the Committee's report, the Government set up the Coordinating Committee on Marine Science and Technology (CCMST), its first task being to develop a strategic framework. The problem is that this never materialised in the way the CCMST envisaged it.

The Government published its response in 1991 and did not accept that the framework should be implemented by a strong coordinating body. It said the general science coordination mechanisms in Government were quite sufficient to deal with all of the issues. So the Inter-Agency Committee for Marine Science and Technology came into being. Importantly, it excluded industry and higher educational institutions – I think that was a major omission. With no direct input from industry or HEIs, the very limited funding was provided by NERC. So the remit and the lack of resources severely constrained anything that IACMST could do. It ended up being very much a 'talking shop'. But IACMST does have important meetings which bring together most of the important players from the marine science and technology arena.

The latest IACMST 'retreat' concluded that we need a marine science and technology strategy. Everyone agrees: there is no doubt about it. We suggested that a cross-Government group or committee reporting to the Government's Chief Scientific Adviser was one way to take this forward.

IACMST itself was quite prepared to lead on this and was prepared to provide talent and expertise, but it would need resourcing – and properly. Because IACMST involves the devolved administrations and experts, it could 'hit the ground running' if it were properly resourced and developed. It does, however, need to involve a wider range of individuals and bodies: Government departments, industry, universities, NGOs, professional bodies – all could be, and should be, actively engaged. Again, it will need resourcing and funding. We in IACMST have the basic strategy in place and could start straight away.

Learning from others

Other nations have developed strategies – Portugal, Canada, Ireland and the USA among them – and we can learn from them. There is no point in reinventing the wheel. There is a great deal of useful information in these and there is no reason why we should not pick up on that.

The US strategy was published in January 2007. It has three critical science and technology elements and 20 national ocean research priorities organised around six major themes. They are looking at the issues we are concerned about: increasing natural resistance and resilience to natural hazards; the ocean's role in climate; improving the health of the ecosystem.

In terms of near-term priorities, we need much better ways of identifying what is happening in the oceans and for that we need much better sensor systems. We need to understand the over-turning circulation variability and rapid climate change: these are the same major priorities that the US plan has.

Proper resourcing is required to develop this strategy, but most importantly we need commitment from people. We have to grab the bull by the horns and act soon, otherwise we will be back where we were 20 years ago, and we do not want that. ❐

discussion

Too narrowly drafted. Speakers expressed concern about the draft Marine Bill, arguing that it is too narrowly drafted and does not fully recognise the importance of long term observation systems on ocean behaviour, although its proposals on Marine Protection Zones were welcomed. It was argued that Defra, not the Department of Transport, should lead on the Bill.

Data: an essential commodity for the marine industry

Colin Grant

I would like to express an 'end-user' view of the *Investigating the Oceans* Report. MetOcean is derived from taking the 'met' from 'meteorology' and the 'ocean' from 'oceanography'. We are concerned with things like winds, waves, currents, tides, temperatures, sea ice – and, critically, the impact these have on the installation, operation and design of BP's facilities.

At each stage of a project lifecycle there are various issues to be addressed; MetOcean is just one. Before we even have a licence we need to know what the conditions are in the area. Once we have the licence we need seismic studies to understand the geology before any test drilling.

After deciding an appropriate approach for a location, we get into detailed design and operating criteria. Then we carry out the project and install the equipment – so we need criteria for installation and for project support – then we operate it. Finally, at some stage we will decommission the facilities.

Take the detailed design work on a North Sea project. We need to know what winds, waves, currents, water levels are going to be. We want long-term, quality-controlled information. This is subject to extensive statistical analysis to generate extreme values, operational criteria, etc. Looking at the operations level, again the North Sea is a good example. We run helicopters and supply boats so we need information – again about winds and waves, but for helicopters we need temperature, pressure, humidity, cloud cover and cloud height. We measure those parameters from many of our platforms and Shell also has an extensive network of real-time systems on their platforms. BP has, in the last couple of years, joined together with them so we share information. The data are 'real-time'. Some go into the GTS system of the Met Office and the wave data from Shell Systems go into the CEFAS Wavenet.

Historical data

In terms of making data more widely available, what about archived data? I have been with the company for 23 years, but we have been measuring for longer than that at some of our sites. So there is the SIMORC initiative – System of Industry MetOcean Data for the Off-shore and Research Communities. This is an EU co-funded project, under Framework Programme 6, which started in June 2005.

Dr Colin Grant is Engineering Technical Authority for MetOcean at BP Exploration. After leaving Bristol University in 1978 with a PhD in satellite meteorology, Colin joined Imcos Marine Ltd in Aberdeen. In 1984 he joined BP as a metocean specialist. During his 23 year career at BP, he has generated the design and operational metocean criteria for many of BP's offshore facilities around the world.

The first phase is almost complete. At present, the main players from the offshore side are BP, Shell and Total, working through the international Association of Oil and Gas Producers. The project is coordinated by a Dutch organisation called Maris. The British Oceanographic Data Centre, which is based at Liverpool at the Proudman Laboratory, is responsible for data quality control and formats. Promotion and dissemination is the responsibility the Inter-governmental Oceanographic Commission in the International Oceanographic Data and Information Exchange (IODE) office in Ostend.

We generate science-specific data. While we use this information for our own purposes and that is true of most offshore operators, there is an increasing willingness to share this data. When I joined BP in the 1980s even wind and wave information was deemed commercially sensitive and we would not put it in the public domain, in fact we traded it with other companies. Now the approach of many offshore companies is to say "we've had some value from it, we've had the initial results, can we add more value to it by sharing it on a wider basis?" So we have examples like SIMORC, the North Sea WebMET data network and the Minerals Management Service (MMS) current system.

BP operates around the world in 40 or 50 countries and BP Shipping is running up to 100 ships around the world so we rely on accurate weather forecasts for our operations. The accuracy of those forecasts is intricately linked to the quantity and quality of ocean observations and their assimilation into numerical models, so it is in our interest to make that information available.

We are trying to encourage more of our colleagues in the offshore industry to share their data especially with the scientific community, because we believe the improvement of ocean models, etc, will ultimately help us all.

Government involvement

The global infrastructure for ocean observations requires international cooperation as well as funding at a Government level to provide the basic operational underpinning. Now many industries accrue significant benefits from such global systems. If that makes us more successful, it increases the profits and increases the tax paid.

If we look at the UK, depending on the nature of the marine data and information that either we require or we are making available, we need to approach a number of UK Government departments from BERR and Defra to the Crown Estate, the Environment Agency and the HSE – as well as some of the NERC institutes. Many different departments are involved in some aspects of marine data and marine information. It is not easy to find your way around. For instance IACMST does not have official industry representation. Fortunately it does have invited industry representation, because I sit on the Marine Environmental Data Action Group and I chaired the working group that organised a recent workshop at the Institute of Marine Engineering and Science and Technology.

There is a general willingness to cooperate and share marine data amongst industry and industry associations and Government departments, but we definitely need a unified data policy from them. At the moment there are different policies in different areas.

There also remain some key questions to which we need answers:

- Can access to marine data and information in the various Government departments be improved?
- Do the present systems of licensing and charging for Government marine data and information allow the maximum potential benefit to accrue to the UK economy?
- Can industry rely on the Government to support global infrastructure for operational oceanography which underpins much of the marine forecast service provision that we rely on? ❐

A special meeting on 27 November 2007 celebrated the 30th anniversary of the Foundation for Science and Technology and also reflected on Sir David King's time as Chief Scientific Adviser to the UK Government.

Standing on the shoulders of science

David King

When I was parachuted into Government in October 2000, 9/11 had yet to happen. Climate change was considered a topic needing more research and the Kyoto Protocol had yet to come into force. The UK had not seen an outbreak of foot and mouth for over 23 years. Government was dealing with the repercussions of the BSE outbreak. The science budget was still trying to recover from the cutbacks in the '80s and '90s, while nanotechnology was a mere speck on the horizon. Fusion however, was only 35 years away from becoming a commercial power source … some things never change!

Sir David King KB ScD FRS was appointed Chief Scientific Adviser (CSA) to HM Government and Head of the Office of Science and Innovation on 1 October 2000. Sir David King is now Director of the Smith School of Enterprise and the Environmen at Oxford University.

Animal health

In early 2001, foot and mouth began to grip the UK. John Krebs called a meeting of epidemiologists to discuss the outbreak. Subsequently I rapidly assembled a team of epidemiological modellers, virologists and logistics modellers. The team's models pointed to the need to cull all animals infected with the disease within 24 hours and all neighbouring farms once the virus was confirmed. If this were done, they confidently predicted, the outbreak would be virtually eradicated by the middle of the year. Within a few days, this new strategy was being implemented throughout the country and the result was what had been predicted by the modellers.

After eight years of experiments by scientists around the world into BSE, samples of sheep brains had apparently been found to contain the disease. Before any announcement was made to cull the UK's sheep I asked a simple question. Were we sure they belonged to sheep? Had anyone undertaken a DNA test? The answer was no. An additional sample was then sent for testing which showed absolutely no trace of sheep: someone had mixed up the cow and sheep brain samples. A clear example if ever I saw one of the need to label clearly, and to check labelling with scientific tests.

But the biggest challenge is TB in cattle. Over 20,000 animals have been slaughtered for TB reasons in Britain each year since 2002, and this is currently costing the taxpayer £80 million a year. Badgers have now been conclusively shown not just to harbour bovine TB but also to pass it on to cattle. I have recommended that, in those areas where TB is particularly rife in cattle, we should cull not just the infected cattle but also a proportion of badgers. Badgers are the major wildlife reservoir of TB in our farmland. TB testing in cattle would need to continue and any infected animal slaughtered. But culling a portion of the badger population would be an effective way to reverse the spread of the disease until better solutions, such as vaccines, could be found.

Human health

In 2005 there were three main BSE controls. The principal one was the removal of bovine organs and body parts most susceptible to BSE infection, such as spinal cord, to prevent them entering the food chain. This control removes over 99 per cent of the infectivity in cattle and will remain in place. The second was the prohibition on mammalian meat and bone meal being fed to farm animals. This will also remain in place. The third control, the Over Thirty Months (OTM) rule, stopped cattle over that age being used for human consumption.

The OTM rule was introduced in 1996, following the establishment of a link between BSE and vCJD. The potential additional exposure from lifting this rule was extremely small while it offered poor value for money in terms of public health protection (over £1 million per day). The rule was abolished in 2005, a clear case of Government finally listening to the science.

GM

The GM Science Review I chaired reached a sensible conclusion – to regulate products case by case and not reject the new technologies. But the GM Nation debate in 2003 concluded that there was general public unease about GM crops and food, with little support for early commercialisation of GM crops. Yet, by 2050 we will need to feed over 9 billion people on the planet: we will only do this, I believe, through a third green revolution and GM technologies will be crucial to this. British science, in particular molecular biology, is a world leader and we should be producing companies that will lead the world in this green revolution. I believe that it is time to revisit this issue.

Foresight

In the 21st century, we need a way to capture the interdisciplinary knowledge generated in universities and research institutions around the world, to relate this knowledge to risks and opportunities that might arise in the future, and to use this in the development of evidence-based policy. So, in 2002, a new Foresight was created.

The first step in ensuring both that politicians are ready to listen and that scientists are able to speak is to choose the right topics. These must either represent important current issues that science, technology and the social and economic sciences could together help address (for example flood risk management), or current aspects of science or technology that are likely to have wider potential in the future (for example exploiting new aspects of the electromagnetic spectrum).

The subject must be: future-orientated; not duplicating work taking place elsewhere; with potential outcomes that can lead to specific actions; be multidisciplinary; and above all, there must be a commitment from the potential beneficiaries that they are eager to hear the results and act on them.

The results are never simply extrapolations from the present day. Each project must develop an agreed action

discussion

Risk and policy. It was argued that policy-making has to contend not only with objective risk assessment, as it would be understood by the insurance industry, but also with the public perception of risk. If these are out of kilter then there could be a heavy price in economic terms, as happened with GM. It is necessary to take public concerns on board and in the case of GM that has resulted in a world-leading regulatory regime. The public often asked why it was necessary to incur risks at all. When the benefits were clear, as with mobile phones, then public attitudes to risk were likely to be robust and a sound regulatory regime could be constructed.

plan which is widely circulated to all stakeholders and put in the public domain. The primary aim is that Foresight projects will influence both policy and funding decisions made by Government. There is little point in producing scientific reports if nobody on the political side is listening.

The Foresight and Horizon Scanning activities are now embedded in Government thinking and provide the best examples of how Government can use science in its broadest sense to look at the challenges of the future. The publicity given to the recent report on *Tackling Obesities* is a very welcome indicator that these programmes go to the heart of public interest and concern.

The environment

As UK Government Chief Scientific Adviser for the past seven years, I have been actively involved with climate change and related energy issues.

The 10 warmest years on record have all been since 1990. Over the last century average global temperatures have risen by 0.6 degrees Celsius: the most drastic temperature rise for over 1,000 years in the northern hemisphere. The summer heat wave of 2003 killed over 30,000 people. On the basis of a constant climate baseline it has been calculated that such a summer is a one in about 1,000 year event. However, due to global warming the central European average summer temperature is now close to the hottest summer of the 20th century, which was in 1947. By mid-century, the average European summer temperature will be the same as that severe summer of 2003.

The public, in my view, does now understand the scale of the problem we face. A recent opinion survey in the UK showed that 94 per cent are concerned about climate change.

There is a growing consensus on the need for robust and urgent action. The role of civil society will be a major factor. Increasingly large and small private sector companies are involved in taking action to limit climate change. The priority now is to turn the corner towards a low carbon global energy economy, using mechanisms such as emissions trading.

Urgent action is needed now if we are to have an agreement by 2009. First, though, agreement must be reached on four key areas within the G8+5:

- A global stabilisation level (my view is that this should be set at 450 ppm CO_2 equivalent);
- National targets and timescales for all countries;
- Worldwide carbon trading;
- A strategy for technology transfer and adaptation.

Through science we are aware of the problem and, with the necessary political and collective will, have the ability to address it effectively. However this is not a long-term problem: the time to act is now for the benefit of future generations.

Energy

Climate change offers opportunities. If we are to see a step change in energy production and supply we need to ensure that business can make the most of these opportunities. It is vital for business to engage with Government in developing effective and efficient policies.

Companies must also think about how they will make the transition to a low carbon economy. The context for all businesses is set to change radically, with immense opportunities available to improve existing business practice and competitiveness, for example through increased energy efficiency. New products and services, from low carbon technologies to new insurance products, represent great new business opportunities.

The opportunities for the UK should not be underestimated. If we can harness these new low carbon technologies we can really get a march on other countries in terms of technology transfer.

The UK Government is working with the chief executives of BP, E.ON UK, EDF, Rolls Royce, Caterpillar and Shell to develop a new Energy Technologies Institute, which will invest £1 billion in low carbon energy over 10 years. A Director has been appointed, David Clarke, and a location chosen for the hub of the institute at Loughborough University.

However, we are only investing around the same amount on energy R&D as Belgium. A continued step change in investment will be needed. This is just the start.

Alternative technologies and energy-efficiency gains will certainly help the UK to reduce emissions by 60 per cent by 2050. But we also need other low-emission ways of making energy. It is now the time to give the green light to nuclear energy. While I have high hopes for new zero-emissions technologies in the future, efficient nuclear-fission power stations are already available. I am also hopeful that fusion power stations, without the problems of nuclear-waste disposal, will emerge over the coming three or four decades.

I emphasise that I do not believe in direct government subsidies for nuclear energy. The private utilities sector must decide on the economics, guided by Government considerations on emissions targets and the need to have a secure energy supply.

The UK built environment must evolve to help manage the transition to secure, sustainable, low carbon energy systems. The Foresight programme has recently examined the development of intelligent infrastructures and another is under way, on energy efficiency in the built environment. Lower energy usage is a must if we are to reduce our emissions.

Civil contingencies

The UK is not alone in facing a threat from those who believe they can advance their aims through acts of terrorism. Science and innovation have a critical role in countering terrorism. First, we must forge an environment that fosters creativity and innovation and so generate the knowledge and technologies that can reduce the risk. Second, the best available science and innovation must be used to provide support and advice at both the strategic/policy level (Government departments) and at the end-user tactical level, including those responding to emergencies or involved in clean-up and recovery.

The role of social science in counter-terrorism is key. Finding ways to integrate people into societies by winning hearts and minds will be vital in preventing individuals from becoming involved in terrorism.

We must also continue to evolve our thinking. We must ensure that Government departments work more closely together, and that science and innovation are deployed to maximum effect. We must clearly articulate the priorities for new research, engaging established multi-national companies, imaginative entrepreneurs operating in small

discussion

A balancing act. All Chief Scientific Advisers have to walk a thin line between keeping the confidence of ministers through their discretion and keeping the confidence of the public in their independence. Controversial public statements are like the nuclear deterrent, to be kept in reserve and only brought out when other avenues seem too slow, as was the case in the early debates on climate change science.

or medium sized enterprises (SMEs), and academia.

Science in the Civil Service

In the early 80s there was a coordinated campaign to encourage Civil Servants to use legal advice. Called 'the judge over your shoulder' it was incredibly successful and ensured that Government was more legally-minded. During my tenure as GCSA I have worked hard to integrate science and policy making. I have been impressed with the quality of people in the Civil Service but it is clear that we need to do more to ensure we have a scientifically literate civil service, able to make the right decision based on the very best evidence.

The UK should be well placed to take advantage of globalisation. We have an excellent record of scientific discovery and a rapidly growing share of high-technology manufacturing and knowledge-intensive services in the UK. Knowledge transfer from British universities has increased significantly and we are beginning to see the growth of exciting high-technology clusters around many of our world-class research universities. The problem – and one that I have tried to tackle – is how do we grow the next IBM or Nokia? We are very good at growing small to medium sized companies but when it comes to the next stage, we struggle. We need to coordinate public sector support for technological innovation, leverage public sector resources and simplify access for business.

We also need to improve procurement capability; Government currently spends over £120 billion a year here. I would like to see one or two per cent ring-fenced to encourage promising new technologies. This risk procurement policy would not only pull through new technologies of direct use: it would also stimulate the development of more R&D companies in the UK, large and small.

International activity

In the summer of 2004 a group of scientists went to Indonesia and Bangladesh to warn the governments of a potentially devastating earthquake hitting the region and to ask for the establishment of an early warning system, at a cost of $30 million. This request was not acted upon and less than two months later an earthquake in the Indian Ocean caused a massive tsunami, killing almost 300,000 people and causing billions of pounds of damage. What does this tell us? Ignore scientific advice at your own risk!

This is an extreme example of not taking on board scientific advice; however it is and should be a clear and stark message that science and a good evidence base is integral to tackling the challenges of the 21st century, whether the environment, resources, food production, water resource, terrorism or wealth creation.

As a society we face a number of challenges for the first time ... It is science and technology that will provide the answers, provided the political climate is right.

More than ever before we live in a global age; we can access vast quantities of information from all around the world and interact with a far greater diversity of people. Advances in science, engineering and technology underpin the changes we have seen. The ability to innovate, adapt and use this knowledge has changed the way all of us live, work and communicate. However, world poverty and sustainable development remain serious challenges where science and technology have a critical role to play.

In 2004, the UK Government asked me to set out a long term vision and investment commitment in the Science and Innovation Framework 2004-14. The Global Science and Innovation Forum (GSIF) was formed as a result, in recognition that science and innovation are international endeavours where the UK must be an effective and active global player.

The GSIF strategy was based on four priorities:

- research excellence;
- excellence in innovation;
- the utilisation of our global influence;
- development.

We need to use our own progress in research and innovation to assist developing countries and to help meet international development goals.

I am an advocate of investing in science, technology and innovation (and, as befits the new Department for Innovation, Universities and Skills, the wider skills development agenda) for the sustainable economic development of the poorest countries. Whilst the Millennium Development Goals have focused on primary education for all, I have passionately argued for a more holistic approach encompassing primary, secondary and tertiary education as well as professional training.

The Commission for Africa articulated this well – after much lobbying – in its 2005 report, when it called for significant investment in centres of scientific excellence and in higher education institutes. The report informed the G8 Summit at Gleneagles, during the UK's G8 (and for that matter EU) Presidency. 2005 was, I believe, a turning point in African development as we began to think of a real partnership with the continent.

Nevertheless, little attention is yet being paid to the need for highly trained scientists, engineers, medical practitioners and agriculturalists. This is a recipe for disappointment, and is a challenge that I hope will be addressed – with UK leadership – by science policy and research communities alike. I believe we have the framework now to tackle this issue.

As a society we face a number of challenges for the first time: using natural resources sustainably; reversing environmental degradation; defeating infectious diseases; and tackling climate change. The questions we ask come from our scientific understanding of risks and opportunities. It is science and technology that will provide the answers, provided the political climate is right. ❐

discussion

The nuclear option. Nuclear power could have a significant contribution to make to a cleaner energy mix. Support has been obtained for international cooperation (at the Cadarache centre) on fusion research and, although still some years from fruition, progress would be faster with greater funding. Now is the time to consider the role of the private sector in advising how the technology could be taken to market.

Following Sir David's speech, speakers from Government, industry and the media spoke about the impact of his time as Government Chief Scientific Adviser. Summaries of the talks given on that evening are printed below.

The role of science in public policy

John Denham

The department that I head is inevitably going to be shaped hugely in our future work by our heritage of David's work. Of course it has not always been uncontroversial: from his early years in South Africa (where his reaction to the apartheid regime effectively forced him to pursue his career abroad) to his clear attempts to win the hearts of organic farmers, the anti-nuclear movement and, of course, badger lovers everywhere!

I first became aware of David's work when I was a health minister and I received a phone call - it may have been Easter weekend in 2001 - from Number 10 Downing Street. The gist of the message was: "John, I don't know if you've noticed, but we've got an awful lot of dead cows and it appears we can't burn them or bury them; would you mind trying to sort it out for me?"

I then came across him when I was at the Home Office, where I hope I gave some support to his insistence that we should have a Chief Scientific Adviser. I think there are now nine senior scientists employed in major Government departments.

Looking at my new department Sir David's legacy could not be more clear. We start from this wonderful base of the greatly-expanded and ring-fenced science budget and the Science and Innovation Strategy, which has given us the framework to expand and rebuild the reputation of British science. Then there is the Energy Technologies Institute, as well as the Global Science and Innovation Forum which aims to make the UK the partner of choice for global business looking to locate its R&D activities. I recently had the opportunity to visit China, opening the Research Councils' UK office in Beijing, looking at a number of the collaborations taking place between British and Chinese universities. The payback, for the Government and the country, is already very clear to see.

The Rt Hon John Denham MP was appointed Secretary of State for the new Department for Innovation, Universities and Skills (DIUS). The Department was established on Prime Minister Gordon Brown's first day in office and combines parts of the former Department of Trade & Industry (DTI) and the Department for Education and Skills (DfES). Mr Denham previously had served as a Minister following the election of the Labour Government in 1997.

David set up and chaired the Council on Science and Technology – I was recently discussing their report on the technologies most readily exploitable within the next five years. He carried out groundbreaking work on nanotechnology and its implications. He also led development of the G8 Science Carnegie Group, aiming to bring science to bear on international public policy.

The work of my department and the rest of Whitehall, as the Prime Minister has made very clear, is going to be shaped by David's success in putting climate change on the political agenda here and abroad.

It is nearly 50 years since C P Snow wrote of the two cultures - the scientific and the non-scientific - and the implications for decision making in a modern society. In making real progress to break out of those cultures, Sir David's insistence on the importance of the scientific understanding of public policy issues has been crucially important.

There remains some confusion about the role of science in public policy. Some fear it means devolving public policy to scientists, rendering the democratic process (or for officials, the bureaucratic process) irrelevant because everything is handed over to a committee of experts. Of course nothing could be further from the truth; science does not do away with politics or democracy. It does not remove the choices about which issues to tackle, which selections to make of the available policy tools or, fundamentally, about the values that are going to inform decisions.

To me, science simply enables us to understand properly what those issues are. It forces us sometimes to confront issues we would rather not think about, and issues that may not yet have found their way into our constituents' emails. It enables us to understand the difference between real choices and those choices that could not work.

Throughout his career, but most recently as Chief Scientific Adviser, Sir David King has worked tirelessly to get us to understand that role of science. There is still a way to go, I agree with him, before the decision-makers in Whitehall and in Westminster have learned to understand and appreciate the role of science. Nonetheless, David has done a job for which I think we should all be very grateful indeed. ❐

Informing and persuading

Iain Conn

Whoever is in the office of Chief Scientist must live with the worrying realisation that his judgment is always on the line while his advice is likely to be called upon at very short notice and often in a crisis situation. Scientists (like businessmen) do not always make good politicians, but the Chief Scientist has to be both. His scientific credentials, expertise and impartiality have to be demonstrable – but he must also know how the political game is played. David has mastered this brief.

David also has the ability to make complex scientific issues understandable and interesting to the layman (I include politicians and business people as laymen, although we might not always want to admit it). Let me add here a personal observation about one of David's key traits. He is a remarkable communicator – lucid, energetic, persuasive. Has this mattered in his role as Chief Scientific Adviser? I think it has; not only in the first crisis that he confronted over BSE, but in the evolving debate on climate change.

For BP, it is probably in the areas of energy security, low carbon energy and climate change that we have felt David's

leadership most. He has been fearless in drawing attention to the seriousness of climate change and the need for action. He has used language which sometimes has got him into trouble but as a result has ensured that the issue was not ignored politically. Before Al Gore, there already was David King!

Another example of his leadership and drive is the newly formed Energy Technologies Institute (ETI). We believe ETI will turn out to be a groundbreaking piece of government-industry collaboration and similar models are appearing around the world, such as in China. It will create a new model for addressing one of the key issues of the day – the level of R&D in energy technologies.

Energy security, energy supply and demand, and climate change are inextricably linked: technology and energy policy/ regulation are at the heart of the solution. This is what David has been emphasising and will turn out to be one of his greatest legacies.

The challenges we face – be they in the area of low carbon energy or stem cell research, for example – will all require innovation and efficient investment, and crucially will rely on the right partnerships between Government, the public and industry. David King has made a major contribution to this; not only by energising the Government's contribution and facilitating the dialogue with business, but by consistently and clearly explaining to a wider public why the issue matters and why actions have to be taken.

I have seen this for myself and I believe we are all in his debt. ❐

Iain Conn is Chief Executive for Refining and Marketing at BP. He also holds regional responsibility for Europe, Southern Africa and Asia Pacific. He is chairman of the advisory board of The Imperial College London Tanaka Business School and a member of the advisory boards of the Centre for European Reform and of the Centre for China in the World Economy at Tsinghua University. He is also a non-executive director of Rolls-Royce Group plc.

Using science to inform policy making

Pallab Ghosh

The Chief Scientific Adviser is the 'point man' for science within the Government. However, the man in front is often the one with the highest profile – the one that gets the most plaudits but also the first in the firing line. From my viewpoint, the job involves helping Government deal with civil emergencies. And it is also to help interpret the constant and sometimes contradictory babble of information the politicians have to deal with.

For an outsider, Whitehall seems a bewildering world. Each department is a complex, well meaning, but often fiercely protective bureaucracy. And the departments continue to make critical and avoidable mistakes. The role of a chief scientist is to make sense of the Whitehall clamour.

The making of Sir David was his handling of the Foot and Mouth Crisis in 2001. The epidemic was spiralling out of control. But with the help of Lord Krebs he pushed for a policy of contiguous culling. It was politically unpopular – the vets did not understand it and did not want it. Ministers loathed the pictures of the sun being blotted out by the smoke from burning carcasses. Yet it was the right thing to do and, despite tremendous pressure, he fought for that policy to continue. That won Sir David the confidence of the Prime Minister – but more importantly the public.

Climate change

He will perhaps be best remembered for his work on climate change. My own impression is that in 2003 the Government did not think that climate change was important. The Brownites were wary of the economic consequences of tackling CO_2 emissions. And at the time it seemed that the Blair camp wanted to take the path of least resistance. So Sir David did as any dutiful civil servant would: he wrote the now infamous article in *Science* magazine in which he said that climate change posed a greater threat to the world than international terrorism. No quiet working behind the scenes for him!

I believe that was the moment when Sir David gained the Prime Minister's attention. It started the process that persuaded the Prime Minister to put climate change and Africa at the top of the agenda for the Gleneagles Summit in 2005. And it was that summit that pushed climate change to centre stage internationally.

Pallab Ghosh is the BBC's Science Correspondent. Pallab has been a science journalist since 1984. He worked for *New Scientist* as science news editor before joining the BBC in 1989. He has worked as a general news producer on BBC Radio 4's *World at One* and as a senior producer on the *Today Programme*. He is President of the World Federation of Science Journalists and is a past chairman of the Association of British Science Writers.

What has been important to me and the public is Sir David's willingness to engage with the media. It makes a huge difference to good, accurate reporting if the Government's chief scientist can tell the media, and in particular specialist science correspondents, just how it is.

To my mind Sir David's chief asset has been his passion. Critics have argued that that this is also his weakness. They say it has led to blurring of scientific and policy advice. His advocacy for nuclear power is a case in point. There has also been concern that much of it has been about personality and celebrity rather than process and policy – Sir David rather than the issue at hand being the story.

I recognise these criticisms. Yet in my experience there are too many committees and stakeholders in Whitehall, too much watered down consensus. Sir David, on the other hand, has been the latest in a line of Chief Scientific Advisers who have been independent-minded and told ministers and Prime Ministers exactly what they thought. All of them have at times raised inconvenient truths and sometimes they may have overstepped the mark. But better that, in my view, than being yet another timid cog in the broken Whitehall machine.

I feel Sir David's lasting legacy has been to introduce departmental scientific advisers and to boost their role. The new CSAs along with Sir David have been fighting the quiet battle that the Foundation has been involved in for 30 years: to employ science to inform policy making for the betterment of society and the planet. ❐

Research Council funding priorities

Ian Diamond

The Science Budget settlement for the period 2008-2011 announced in the 2007 Budget represents an average annual growth of 5.4 per cent over the Comprehensive Spending Review (CSR) period. Comparing this with the settlements for other public bodies, the science settlement is extremely good. It reflects a continuing commitment from the Government to invest in the research base, for which the Research Councils are grateful.

The settlement is based on many discussions with the Department for Innovation, Universities and Skills (DIUS) and before that with the Department of Trade and Industry. These have led to the publication of the delivery plans for the seven Research Councils and also Research Councils UK (RCUK). This article provides an overview of our collective priorities and some of the thinking that underlies them.

Perhaps the most eye-catching part of the RCUK delivery plan is our support for multidisciplinary and transformative research, and in particular six major research programmes that tackle major national and international challenges

These are:

- energy;
- living with environmental change;
- global threats to security;
- ageing research: lifelong health and wellbeing;
- nanoscience through engineering to application;
- the digital economy.

These programmes will bring researchers together from a wide range of disciplines and will involve organisations from across Government and business. We also recognise that the challenges they seek to address are inter-related: for example, energy provision is important in addressing environmental change, which in turn can be a major cause of insecurity and conflict. RCUK will provide the strong coordination that is required.

Our interest in these areas is not new. In particular, the energy programme builds on an existing initiative, while significant resources from across Councils have addressed environmental change and several cross-Council ageing programmes have been undertaken, most recently New Dynamics of Ageing which was launched in November 2006.

The new programmes are noteworthy in their size. The DIUS Science Budget Allocation Booklet, published on 11 December, reveals that three of the programmes will receive over £300 million over the CSR period but the programmes will continue to support research for several further years. The Living with Environmental Change programme is also supported by several Government departments and agencies, with a combined investment of £1 billion over five years.

Professor Ian Diamond has been chief executive of the Economic and Social Research Council since January 2003. He chairs the Research Councils UK Executive Group, a committee comprising the seven Research Council chief executives. Previously, he was Deputy Vice-Chancellor at the University of Southampton.

Our programmes are not simply expanded versions of their predecessors. They start with fresh objectives – but if existing research programmes are consistent with these, they will be incorporated into the new programmes.

In addressing societal challenges, RCUK will ensure that the beneficiaries – i.e. the public – are engaged in the work. RCUK has recently undertaken public engagement projects in ageing and energy: a challenge for the CSR period is to embed this type of science-in-society work across all our cross-Council research programmes.

This work will also complement the incentives we provide to researchers to engage with the public. In a study we funded with The Royal Society in 2006 there was a welcome desire on the part of researchers to undertake public engagement but the reward and recognition was deemed lacking. During the next CSR period, we will address this via a network of Beacons for Public Engagement. Funded by the UK Funding Councils, RCUK and the Wellcome Trust, the Beacons initiative (worth £9.2 million over five years) will support a step-change in recognition for public engagement across the higher education sector.

The international dimension

International collaboration benefits all partners. By stimulating new partnerships, we can further strengthen our reputation for research. The next three years will see a stronger emphasis on this. The UK has a good record of building and sustaining global partnerships. We need to develop this further since emerging economies are investing rapidly in their research bases, providing new opportunities for UK researchers to collaborate.

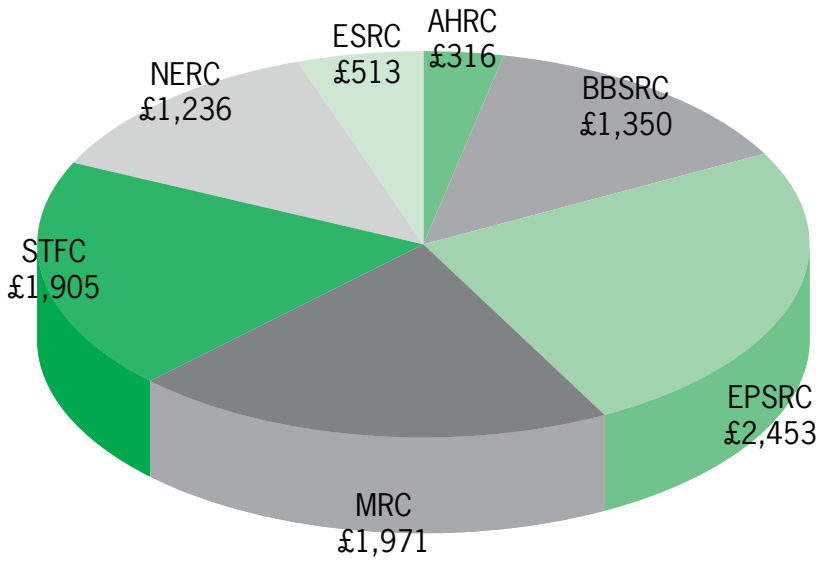
The Research Councils are active and enthusiastic partners of the Government's Global Science and Innovation Forum (GSIF), which brings together public funders of research. A significant recommendation of its *Strategy for International Engagement in Research and Development*, published in October 2006, was that we should work together more closely, through the RCUK partnership, in order to provide a single point of contact for researchers and research funders. We have begun to implement this recommendation and have opened offices in China and the USA. We will take this further during the CSR period. We are hopeful that we will be able to open an office in India during the first part of 2008 and we will explore other mechanisms for stimulating collaboration in other countries, such as Brazil and Japan.

In parallel with our joint operations overseas, we will strengthen our collective activities in the UK. To this end, we will be setting up an RCUK international team and a cross-Council international group, chaired by Nigel Brown, Director of Science and Technology at BBSRC. Our focus will be on removing obstacles to collaboration, promoting opportunities for UK and overseas researchers to work together and also promoting the international profile of the Research Councils as well as the reputation of the UK as a world centre for R&D.

Maximising economic impact

Over the CSR period, the Research Councils will strive to maximise their economic impact across all their investments, through their research and training programmes and from their facilities. On 9 October 2007, RCUK published its report *Excellence with Impact*. This reveals the substantial impacts arising from past investments and sets a path to increase these further. A key part of this strategy is the flourishing relationship between the Research Councils and the Technology Strategy Board (TSB). Over the next three years, Councils will invest £120 million in collaborative projects with the TSB.

This is not a diversion of resources to the TSB. Proposals will still be subject to



Science Budget allocations to the seven Research Councils for the three years of the CSR07 period (£ million).

peer review and funding allocated on the basis of excellence. In November last year the TSB announced seven priority areas for its collaborative R&D programme. All these areas are currently receiving Research Council funding. The significance of this announcement is therefore that we will be aligning our funding with the TSB's programmes as a means of deriving the greatest impact from our investment in these areas. We will also work with the TSB to stimulate interest in the private sector of new technologies emerging from the research base.

Our activity in this area has provoked alarm over an apparent shift from basic to applied research. Research Councils are committed to supporting basic research but our Royal Charters clearly state their role in deriving benefit from their investments and we have been devoting significant resources in the past to achieve this. We recognise, however, that the pressures of globalisation mean that we need to embed economic impact considerations across all of our activities.

The researchers we fund are in receipt of taxpayers' money and this must be spent wisely, efficiently and with maximum benefit. When you invest in a pension fund you would want to maximise the yield at retirement age and this means a balanced portfolio of investments, but you would want each element – high- and low-risk alike – to achieve significant returns over the long term. The Research Councils seek to adopt the same 'balanced portfolio' approach. We look forward to working with the research community to achieve this – but we must all remember that the Government's interest in research is not philanthropic.

We now have good evidence of economic impact across the full range of our investments. The RCUK *Economic Impact Study*, published last October, demonstrated that, in research investments as diverse as polymer chemistry and surrealism, the benefits have been significant. The study also provided insights as to how to increase these benefits still further: one of these being that we should not reduce our commitment to long-term research investments.

We will be aligning our funding with the Technology Strategy Board's programmes as a means of deriving the greatest impact from our investment in these areas.

Engaging young people

We recognise the need to attract the best people into research careers and keep them there. By engaging young people with contemporary research, though, RCUK hopes not only to enhance their experience of science and encourage more to pursue science studies beyond 16 and thence into R&D careers, but also to educate informed citizens. A particular recent success for RCUK has been its support of continuing professional development for science teachers through the UK Science Learning Centre Network funded by the Department for Children, Schools and Families.

The RCUK Contemporary Science in the Classroom scheme is designed to stimulate teachers' interest in their subject by providing courses that link them with research and researchers. RCUK will fund further development of this scheme during the next CSR period – £1.1 million over three years. RCUK will also be working to make research career paths more visible and will promote the use of enhanced stipends and salaries.

Developing skills

Today's researchers need a broader range of skills than ever before. The 2002 Roberts Report, *SET for Success*, resulted in a significant change in the way we support researchers in developing their skills. Using new funding – the so-called 'Roberts Money' – RCUK has stimulated innovation in the range and delivery of transferable and career skills, in particular for research students.

It now intends to build on this success and promote better career development and training throughout the early career of researchers. RCUK has announced a new £15 million Researcher Development Programme which will build on the success of the previous UKGRAD Programme. The Research Councils will also continue to invest £20 million per annum though single coordinated payments to higher education institutions to fund the training of transferable and career skills. One particularly important area is enterprise skills for researchers and RCUK will encourage close links with industry to deliver the necessary training.

The Comprehensive Spending Review will enable the Research Councils to ensure the long-term health of UK research. All new Research Council grants are awarded on the basis of the full economic cost of the project, with Councils funding 80 per cent of that figure. With the new Capital Infrastructure Fund (the successor to the Science Research Infrastructure Fund) closely aligned with Research Council funding, the Science Budget will in effect fund around 90 per cent of the full economic costs of a research project. This is real money being delivered to support the research base and will ensure that higher education institutions have the funds to invest in their research infrastructure.

A final priority for the Research Councils during the CSR period is for us to explain what we are doing, why we are doing it and what we achieved. I am grateful to the Foundation for this opportunity to set out our plans for the next three years. ❐

Professor Sir Howard Dalton FRS

8 February 1944 – 12 January 2008

Howard Dalton joined the Department for Environment, Food and Rural Affairs (Defra) shortly after the Department had been created, largely from the ashes of the Ministry of Agriculture, Fisheries and Food (MAFF) which had been severely criticised over its handling of the foot-and-mouth outbreak in 2001. This crisis had rekindled memories of an equally difficult time in dealing with the BSE outbreak a decade before.

At Defra, he established a mechanism to ensure that the Department had adequate access to virologists and oversaw a forward vaccination centre that could be brought into operation within three days of an animal health scare. He formulated a policy to cope with bluetongue outbreaks and set in train research to find an effective preventive vaccine.

Another major policy issue facing the Department was that of genetically modified organisms (GMOs). The natural tendency of scientists to debate and experiment do not always sit well with governments, which wish to be seen to have a clear single view. Dalton was highly critical of plans to conduct widespread GM crop trials, claiming that the potential environmental impact of these had not been properly thought through.

He said that GM crops were not "wholly good nor wholly bad", but believed that the UK would one day grow GM crops in a properly controlled environment. He thought that their commercial exploitation was inevitable. He saw the public's hostility to the technology as damaging to applied science here as the UK had been the world leader in this area.

While he did not always see eye to eye with the Department on policy choices, he also sometimes disagreed with his fellow scientists. He regarded wind turbines as too expensive and an 'eyesore'. On the other hand, he was a strong supporter for Environment Secretary David Miliband's strategy to grow fuel crops. He stuck to what he believed in and was always prepared to stand firm over a scientific argument.

The scientist

Howard Dalton took an early interest in science. It has often been related how, at the age of 10, he mixed a cocktail of chemicals in a dustbin which promptly exploded! The first member of his family to go to university, he studied microbiology as an undergraduate at Queen Elizabeth's College, London University. He went on to a doctorate at Sussex University followed by a time at Purdue University in the USA where he continued his research on nitrogen fixation. It was here that he met his wife, Kira.

He moved back to Sussex in 1970, where he studied enzymes involved in bacterial oxidation of methane (methane monooxygenases) which produce methanol. He was then persuaded by Professor Roger Whittenbury to take up a lectureship in microbiology at Warwick in 1973. Here, he studied the metabolism of bacteria growing in unusual positions, using organisms isolated from the hot spring waters of Bath, high in metallic elements and methane.

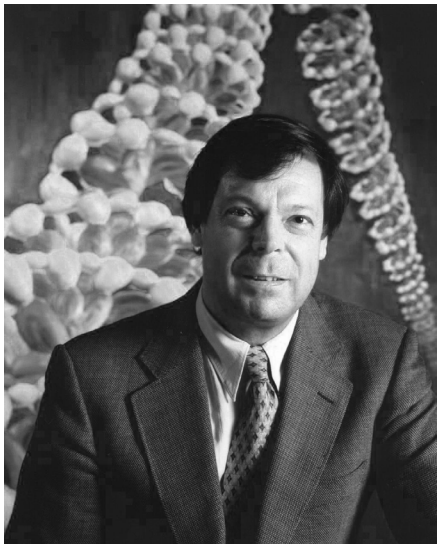
He studied the structure, function and regulation of enzymes in bacteria responsible for consuming methane in the environment, which help to mitigate the effects of global warming by this greenhouse gas. He opened up a new area of research into methane monooxygenase and related metal-containing enzymes and was considered to be one of the best scientists worldwide in his field. Dalton realised the potential of microbes for the production of chemicals on an industrial scale using biotransformation.

Dalton was passionate about science but also about communicating its benefits.

He continued the connection with Warwick until his death, building up a large research group there and being awarded a personal professorship in 1983.

Recognition

Howard Dalton was made a Fellow of the Royal Society in 1993, was President of the Society for General Microbiology, 1997-2000, received the award of the Leeuwenhoek Medal Lecture at the Royal Society in 2000 and was given a knighthood in the New Year's Honours list in 2007. He was Chair of Biological Sciences at Warwick from 1999-2002. After he stepped down as CSA at Defra, he returned to Warwick in late 2007 to lead his research group again full time.



Wider interests

Dalton was passionate about science but also about communicating its benefits. He published over 200 academic papers in his lifetime. He is remembered as an engaging and entertaining lecturer and during his time at Defra he made a two-week visit to the British Antarctic Survey: his blog of his experiences attracted both lay people and scientists to read it.

With his wife, Kira, he was building a medical centre in The Gambia, and implementing a programme of innoculating its children against malaria. They had helped to construct six schools in the country. He was also helping the Gambian government with a number of environmental issues.

He was a man with wide interests. His enthusiasm and knowledge of Japanese gardens resulted in the creation of two such gardens at the university. As well as being a lifelong supporter of Tottenham Hotspur, he played cricket and football in his earlier days and was an enthusiastic and competitive player of Real Tennis. It was while playing a doubles match at Leamington Real Tennis Club that he collapsed and died.

He is survived by his wife, his son and daughter and two stepsons. ❐

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