



Environment on the Edge

2007/08

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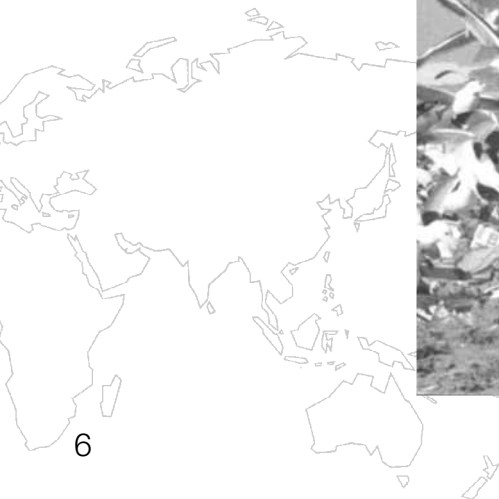




Northern Ireland: an environment on the edge

Professor Sharon Turner

October 2007



Speaking to you this evening it is not entirely clear whether Northern Ireland's environment is at the edge of an abyss, looking into a very black hole, or whether it is standing at the beginning of a bright new future as an era of more stable devolution begins. We are a society in a state of transition, with the new government just recently installed and yet to give us an indication of the likely direction of travel for regional environmental policy. But rather than focus on the individual details of that policy, I shall simply tell you the story of where Northern Ireland and its environment have come from and where I think they are heading.

It goes without saying that for many years the environment in Northern Ireland was essentially a non-issue, with human rights, equality, victimhood and security dominating politics and policy. However, as the peace process has consolidated and the economy has begun to stabilize, the environment has come dramatically and somewhat unexpectedly to the fore. There is now a sense that, whereas once we were seemingly determined to destroy our environment, both the government and people of Northern Ireland are beginning to recognize this very unmet challenge.

Before we get much further it is worth pointing out that the pressure for reform has come in waves – and not always from within Northern Ireland. But it has undoubtedly culminated in a number of very important changes, most recently the launch of a thorough-going Review of Northern Ireland's arrangements for environmental governance, commissioned by the Secretary of State, Peter Hain, in which I have taken part as a panel member.

Although the Review was commissioned by the direct rule government, it was nevertheless viewed by many as a policy signal that those in power were now ready to embrace an ambitious programme of reform in the sphere of the environment. Towards the end of the Review period, devolution was restored and so we presented our final report, *Foundations for the Future*, in June 2007 to Arlene Foster, the Democratic Unionist Party's Minister for the Environment in a devolved administration. Its response to the Review will undoubtedly be a litmus test of where Northern Ireland and its environment are likely to go over the next few years.

Northern Ireland and its environment are at a crucial juncture. The region's economy has been crippled through years of conflict and there is enormous pressure for recovery and regeneration. The



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Troubles have left a legacy of severe social deprivation and a wide range of unmet policy needs. Although the environment is undoubtedly a key economic, social and cultural asset, its importance has yet to be grasped by the new government and there is little shared civic sense of it being a public-interest issue. We have the heaviest ecological footprint in the United Kingdom, and reorienting our society to take account of the environmental challenges of the present – not to mention the future – is going to be an enormous task for its people, its government and its NGO community.

To a considerable extent the scale of official neglect of Northern Ireland's environment can be viewed or understood through its failure to engage with the evolution of European Union law and policy on the environment. Whereas the European Community started to take a lead role in driving environmental policy in the 1970s, Northern Ireland started its steady decline into the Troubles. In effect, while the rest of the United Kingdom and Europe were beginning to turn their attention to addressing the environment, policy making in Northern Ireland was consumed by issues of security, human rights and a collapsing economy.

Twenty years later, by the early 1990s, the House of Commons Select Committee on the Environment came to Northern Ireland and carried out the first independent analysis of the state of its environment. One of the major findings to emerge was government's endemic neglect of environmental EU law. Although Northern Ireland was bound by EU environmental directives as part of the United Kingdom, it had simply ignored the vast majority of them. At that time, of course, the EC was about to amend the EC Treaty to give the Court of Justice the power to fine Member States for non-compliance with Community law, and so Northern Ireland represented a significant financial liability for the UK. Although government in Northern Ireland undertook to clear the EU backlog, a decade later it was obvious that the pace of legislative change was insufficient to remain abreast of EU developments in this field – much less to clear the backlog of unimplemented EU environmental directives.

By 2000 it became obvious that the European Commission had run out of patience and was no longer prepared to allow Northern Ireland – or indeed the United Kingdom – to let the situation continue. More importantly, full legislative powers had been devolved to the Assembly in the previous year, but with devolution came the transfer of liability for the payment of fines incurred as a result of failure to comply with European legislation. EU litigation for non-compliance, combined with the

transfer of liability for payment of EU fines to the devolved administration, generated the first effective stimulus for major modernization.

In the autumn of 2001 I was sitting in my office at Queen's University when I received a phone call from the new Head of Environmental Policy in the Northern Ireland Department of Environment (DOE), asking me if I would like to help resolve (rather than continually highlight) the crisis that was by then facing the department. There began a fascinating two years in which I took a secondment to the Northern Ireland DOE, and assisted them in handling a vast range of litigation from the European Commission and in driving the single largest legislative programme brought before the new Assembly by any Northern Ireland department at that time. Practically every single area of environmental policy was subject to EU litigation, with the threat of very large-scale EU fines looming – large enough to make a major dent in Northern Ireland's budget.

At the time that I joined the DOE I had been studying the Northern Ireland situation quite closely for some years. As an informed observer I knew that the DOE was facing an environmental policy crisis; however, I did not realize just how difficult the situation was until I actually started to open the files. In effect, I began to observe at close quarters the culture of government forged during 30 years of direct rule and 30 years of policy vacuum. First of all, we had a whole generation of civil servants with virtually no track record of complex policy making, much less policy making on the environment. We were also dealing with a civil service that had never been used to policy making in the context of democratic accountability.

Legislation in Northern Ireland during the entire duration of the Troubles was made in Westminster by English politicians who spent very little time in Northern Ireland and who were not directly accountable to the citizens of the region. With the exception of controversial criminal justice or human rights legislation, proposed provisions for Northern Ireland often went before the House of Commons late at night with little meaningful debate. Given that civil servants in Northern Ireland had little experience of dealing with close parliamentary scrutiny or the need to justify new legislation, you can imagine the shock of having to bring forward proposals for 45 complex pieces of legislation, including primary legislation with far-reaching economic consequences, to a locally accountable Assembly – almost all of which had to be rushed through in response to EU litigation.

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Not surprisingly, the Members of the new Northern Ireland Assembly, having been kept out of government for many years, were very keen indeed to use their new legislative powers and to become actively involved in the process of law making through scrutiny committees and Assembly debate. Unfortunately, 30 years of direct rule had created an atmosphere of distrust between the two sides. Officials, on the one hand, were frustrated with local politicians who knew very little about policy making or their portfolios, while local politicians distrusted civil servants because they felt they had kept them at bay for decades. So when I found myself as a lawyer trying to explain to the local Members of the Legislative Assembly that the new legislation would have to be rushed through the scrutiny process to avoid the imposition of large-scale EU fines, it caused tremendous tension. But out of that tension came constructive change, a process of learning and far-reaching modernization of the legal framework governing the environment in Northern Ireland.

Official and political recognition of the neglected state of environmental policy making and the consequent EU liabilities resulted in the DOE's Environmental Policy Division receiving the single largest financial allocation in the first programme for government for Northern Ireland – effectively pushing the environment right up the political agenda. Having come from absolutely nowhere, it was suddenly a major policy issue. This may have occurred for the wrong reasons, but at least politicians and senior civil servants were now being forced to look hard at how they had got themselves into this mess and what they were going to do to get out of it. The Assembly Environment Committee agreed to a shortened period of scrutiny for major pieces of environmental legislation which signalled an acceptance of the infraction crisis. However, the Assembly's Committee of the Centre also made clear that the DOE needed to radically alter its internal culture and ensure proactive management of Northern Ireland's obligation to implement EU directives on the environment to avoid a repetition of this compromise of the democratic process.

The media also became fascinated with this tale of environmental neglect and responsibility, and continued to report this story. There was also a significant cultural or psychological realignment within the civil service in this context. Senior civil servants and local politicians were forced to accept that Northern Ireland was no longer a 'special case' in the throes of a civil war, to be let off lightly by the European Commission. The time for endless procrastination was over and action was expected. Over some rather bracing meetings during this period with officials from the European Commission, the UK

Department for Environment, Food and Rural Affairs (Defra) and the Treasury, it was made abundantly clear that Northern Ireland would be expected to comply with EU law as part of the United Kingdom.

The other major realization at that time was the cost and inefficiency of devolution. Northern Ireland has almost fully devolved powers on the environment – essentially equivalent to those transferred in Scotland. So even though our population is only (approximately) 1.5 million, we have the cost of a full apparatus of environmental policy making and liabilities. In addition, as Scottish devolution became more robust, it became clear that Defra would focus more heavily on England and Wales and thereby do less of the thinking for Northern Ireland than it had in the past. If Northern Ireland's economic, social and environmental conditions were to be adequately represented in the development of EU policy on the environment, its civil service and Assembly began to realize that Northern Ireland could not simply duplicate or 'piggy-back' on policy development in Scotland, England and Wales. Northern Ireland needed to develop the capacity to think independently and engage proactively in the complex and fast-moving policy debates surrounding the development of the United Kingdom's negotiating position in Europe.

Devolution was suspended in 2002 – to an audible sigh of relief across the Northern Ireland civil service. Because of the suspension of the Assembly, the DOE was able to rush through the remaining parts of the legislative framework necessary to avoid EU fines. But even though the DOE was ultimately successful in averting the imposition of fines, that period left a (hopefully) lasting impression on Northern Ireland's political and policy communities.

During the period of suspension (2002 to 2007), everybody expected the environmental agenda to go back into the political vacuum from which it had emerged, but in fact it remained high on the radar. I think there were three major reasons for that. First of all, we were fortunate in having Peter Hain as Secretary of State. Whereas previous secretaries of state had been willing to let policy just tick over, Peter Hain was not only interested in the environment itself, he was also determined to bring a conclusion to the constitutional deadlock and force through some major policy initiatives. The environmental NGO community played an important role in keeping the debate alive (I will explain that in more detail in a few moments), and the UK Sustainable Development Commission (SDC) also played a significant role in maintaining the momentum of reform. For many years the SDC had remained a Britain-focused organization, touring London, Scotland and Wales for its plenary sessions, commenting on government



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action in Great Britain while largely ignoring Northern Ireland. By this time, the SDC had become much more focused on policy making on sustainable development issues in Northern Ireland, making regular visits, asking difficult questions, and keeping pressure on local politicians and the civil service, and on Peter Hain's direct rule administration.

To give you a flavour of what Peter Hain managed to achieve during that period it is important to remember that many local politicians had been effectively absolved from the consequences of suspended devolution because direct rule governments had typically made no major policy changes – always waiting for the outcome of constitutional negotiation and the restoration of power to locally accountable politicians. Peter Hain broke from this 'circling pattern' by proposing a range of far-reaching environmental and social policy changes. He suggested abolishing the 11+ exam for school children, which caused enormous public outcry; he introduced the first and long-overdue Sustainable Development Strategy; and introduced a policy to dramatically reduce rural development in the region. Northern Ireland's Planning Service gives planning permission for more single dwellings in the countryside each year than is granted for the rest of the United Kingdom put together. Rampant rural development is almost a part of Irish culture, both north and south of the border, so this new policy statement caused outrage amongst the local populus. Hain also brought forward legislation introducing water charges for the first time as well as dramatically increasing domestic rates to contribute to the cost of upgrading Northern Ireland's very out-of-date sewage treatment infrastructure.

For the first time, local people began to see policy decision making that was going to affect them at a financial, educational and personal level. They started to view the endless constitutional negotiations much more critically, which created local pressure for the restoration of devolution to halt Hain's policy march. In 2007 we had the first election in Northern Ireland in which the constitution was not the only issue under discussion. Development control, water quality, water charging and environmental issues became major electoral questions.

In terms of the NGOs' role, 30 years of direct rule and the absence of devolved or democratic politics had given rise to a vibrant NGO sector in the field of human rights – and equality in particular – but a somewhat timid environmental sector. Rather than leading public campaigns on the environment, Northern Ireland's environmental NGOs had traditionally fostered almost private

relationships with officials, with negotiations taking place behind closed doors. This was partly the outcome of having no levers for exerting democratic pressure but also led to the silencing of this part of the region's voluntary community. But with the restoration of devolution in the late 1990s, key elements of the United Kingdom's national environmental NGO community significantly increased funding to their offices in Northern Ireland, leading to an important rise in capacity. Nine of the region's environmental groups then formed a coalition in 2004 and launched a sophisticated campaign to pressure for regulatory reform. While the period from 1999 to 2004 had witnessed a focus on modernizing the legislative framework governing the environment, attention now turned to the fact that none of it was being enforced, leading to a major loss of public confidence. In addition, because Northern Ireland's environmental regulator (the Environment and Heritage Service) was an executive agency within the DOE, regulatory decision making occurred largely behind closed doors and thereby lacked transparency. The coalition called for the creation of an independent environmental protection agency (which Britain has had for many years). They asked Professor Richard Macrory to produce an initial consultation paper setting out the pros and cons of such an independent agency, and then used this document to lead the debate, highlighting the fact that the government itself was neither driving the issues nor generating public interest. In 2005, the direct rule Minister for the Environment indicated his willingness to agree to structural reform. However, the environmental NGO coalition was meanwhile becoming more ambitious in its demands. Mindful of the fact that any new agency would be operating within a wider landscape of environmental governance distorted by decades of direct rule, they asked for an independent review of the arrangements for environmental governance so that any programme of change would take full account of the wider legacy of direct rule and the need for holistic reform. The Review began in 2006 and was chaired by Tom Burke, with myself and Gordon Bell (from industry) serving as panel members.

Our remit was incredibly wide. Going well beyond the question of regulation, we were asked to look at all publicly funded aspects of the environment and adopt a transparent process. Following months of public deliberation with a very wide cross-section of representatives from central and local government, the private sector, the voluntary and community sectors, agriculture and industry, we launched our report, *Foundations for the Future*, in June 2007. During its preparation – in fact, right up to the last minute – we did not know if devolution would be restored in the short term or perhaps be put into long-term cold storage, making it very difficult for us to design our recommendations. That said, our main

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finding was that the system of governance was not up to the job of meeting current environmental challenges, or the more complex challenges of climate change to be faced for the future.

We acknowledged that government would be overstretched for many years as it turned its attention to leading a post-conflict society forward and addressing a wide range of unmet policy needs. But our underlying message was that the environment is central to both social and economic well-being and could not be side-lined indefinitely. We emphasized that urgent reform was essential if Northern Ireland was to have any chance of a sustainable future.

We have set out a suite of some 40 recommendations designed not to create a state-of-the-art system of environmental governance, but to focus on the most pressing issues demanding reform. It would be impossible here to go into the details, but I'll give you a flavour of the sorts of changes we recommended.

First of all, we agreed with the environmental coalition and with Professor Macrory's report that government should create an independent environment agency in Northern Ireland. Almost to the point of repetition, the people who communicated with us reflected a serious loss of public confidence in the quality of environmental protection. The DOE or government as regulator was simply an unacceptable way forward, not least because of a tremendous sense of lack of public confidence and transparency. Power is hugely centralized in a direct rule context, with little in the way of democratically accountable politics and many decisions being taken behind closed doors. Environmental regulation was a part of that closed system because the DOE itself was a regulator. In addition, this centralized arrangement for environmental regulation meant that Northern Ireland had no environmental champion capable of leading informed public debate on the environment. The governments and people of Great Britain are well used to having vocal environment agencies, but because the Environment and Heritage Service was part of the DOE, which is ultimately comprised of civil servants, it could not be seen to openly disagree with the Minister. In effect, not only was the environmental NGO sector labouring to throw off a legacy of silence, the environmental regulator – as perhaps the most important official voice on the environment – had also been silenced by the structure of governance.

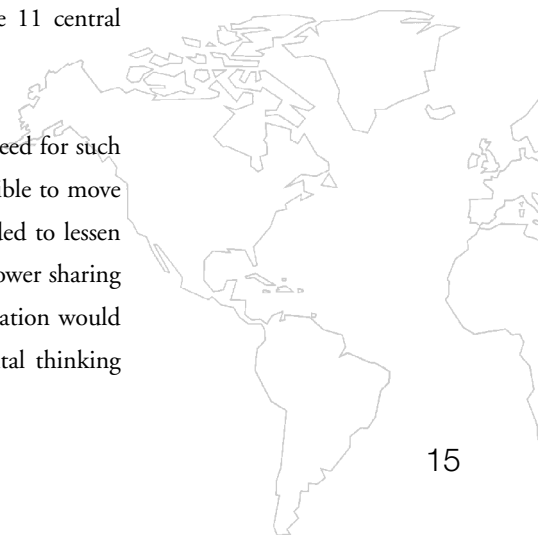
However, we have also recommended an innovative structure for the independent agency. Rather than suggest the creation of separate agencies for pollution control, nature conservation and built heritage

– and partly due to Northern Ireland's scale – we suggested a single holistic environmental regulator spanning all these areas. There are many ongoing considerations of how it might work, but on balance we were persuaded that there are considerable advantages to a holistic approach.

We also emphasized the need to restore regard for the rule of planning and environmental law, which had been significantly undermined during the years of direct rule, while acknowledging the particular challenges faced by the regulator in Northern Ireland. The environment agency, if established, will face the prospect of regulating an international border – the only regulator in the United Kingdom to have to do so – where the illegal smuggling of waste has intensified the problem of controlling serious environmental crime. In particular, the regulator faced the problem of highly armed ex-paramilitaries moving from traditional violence into waste crime, causing many of the most serious incidences of environmental infringement. Regulating such entities poses huge challenges regarding both resources and personnel.

We strongly recommended that the new agency embrace a proactive role in leading and informing public debate and reform. We had given some attention to the barriers to environmental policy making generated by the particular form of government in Northern Ireland. The Good Friday Agreement had created a form of power sharing between the two major parties – the Democratic Unionist Party (DUP) and Sinn Féin – rather than a majority government, with almost all legislative powers on the environment transferred to the Assembly. But in order to create the space for power sharing, 11 separate government departments had to be created, making our small population enormously overgoverned, but also fragmenting responsibility for environmental policy making across nine of the 11 central government departments.

The point we made to government was that while the Review panel understood the need for such a complex central government structure in a power-sharing context, it was almost impossible to move policy making forward without a properly integrated policy system. A framework is needed to lessen some of the worst excesses of that fragmentation. It was clear that the arrangements for power sharing would hamper decision making in any event, but the added effect of structural fragmentation would make it very hard indeed for Northern Ireland to keep pace with modern environmental thinking and reform.

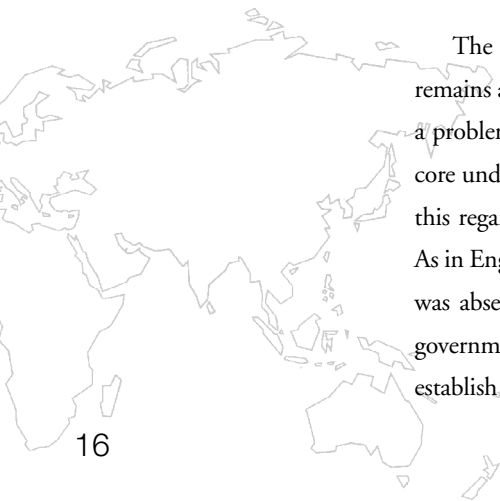


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We also made extensive recommendations about the need to modernize the environmental policy community itself. In particular, we pointed out that Northern Ireland had no strategic vision for the environment. Nobody seemed to know what environmental policy actually was, or even if there was any, and the political parties had little or no environmental policy knowledge. While most of the parties were very enthusiastic, they clearly had no background in this complex area. Government in Northern Ireland had been restored with almost no preparation for government. In Scotland they had spent two years training their prospective politicians in the major policy areas and for the process of policy making. In Northern Ireland the ongoing constitutional poker game had eclipsed all preparation for devolution. We made strenuous recommendations for the independent training of the political parties and also that the Minister for the Environment have a special advisor in this field.

Another major issue for us – and I suppose a defining feature for Northern Ireland – is the island itself. The island context shapes definitively the way in which environmental governance will be played out in future. We are the only part of the United Kingdom sharing an international border and we have our own self-contained island environment. There are powerful legal, political, environmental and economic drivers stimulating the need for proactive collaboration between the North and the South of Ireland. The environment is one of the very few areas identified explicitly by the Good Friday Agreement as a focus for collaboration for the two governments, and we actively encourage them to use the mechanism of the North South Ministerial Council, the Cross Border Bodies and the British Irish Council to come together around this key issue. In our opinion this would serve to develop negotiating alliances for European purposes but also to coordinate policy and regulatory solutions for managing the island's environment.

The importance of enhanced accountability was also a major question for the Review panel and remains a significant issue generally. Needless to say, the democratic deficit of direct rule has always been a problem and, thankfully, as the Review drew to a close devolution was restored, thereby resolving the core underlying lack of accountability. We made two significant recommendations to the government in this regard. First, we recommended that it establish a cross-Assembly environmental audit committee. As in England, we have a suite of scrutiny committees that follow each government department, but what was absent from the system was a cross-Assembly committee which could look at how the whole of government was performing on the environment. We also discovered that it was almost impossible to establish how much was being spent on the environment and whether it represented any kind of value



for money. So our second point was that an annual audit should be published explaining a) how much money was being spent on the Northern Ireland environment and b) what value for money and what environmental value that generated.

We were also struck by the absence of transparency surrounding the entire environmental management process. There is no state of the environment report in Northern Ireland. No-one seems to know whether the quality of the environment is good, bad or indifferent, so one of our central recommendations was to start the process of publishing a thorough state of the environment report on a regular statutory basis. We also recommended that that report be aligned with the Irish state of the environment report so that the people of the island and its governments would see at a holistic level whether the environment was improving or worsening and whether policy initiatives were having the appropriate impact.

Our last major area of focus was the question of environmental justice. This is becoming a major issue in the national and international environmental debate, and has a particularly powerful resonance for Northern Ireland. As a post-conflict society with severe levels of deprivation, we are experiencing a stampede for economic recovery and regeneration, while at the same time ever-tougher environmental decisions have to be taken. In this context of economic and social malaise, the justice implications of environmental governance decisions will be more and more acute, thus we particularly emphasized the need for government to focus on how it would anticipate and respond to these implications.

One of the most important aspects of the justice context was the judiciary itself. In Northern Ireland the culture of the judiciary has been forged through 30 years of responding to and handling serious violence, so it was difficult for them to see environmental crime as a pressing problem. In England, Scotland and Wales it has been an issue for some years, but in Northern Ireland, attitudes to environmental crime are as yet unformed and penalties are considerably lower than in Britain. The temptation for the regulator is to focus on soft targets, be they individual farmers or smaller essentially compliant industries, to increase prosecution and enforcement rates, meaning that serious criminals have often been overlooked. The suite of new powers we recommended would force the regulator and government to enhance respect for the rule of law. We also suggested that the environmental policy cycle begin with an environmental justice impact assessment.



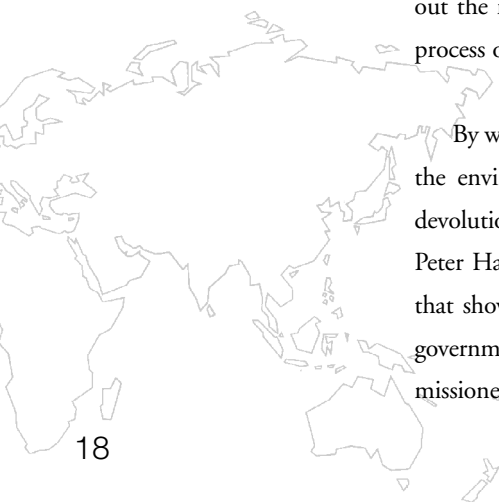
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Northern Ireland has some experience of impact assessments. As a result of our particular political history, we have statutory obligations requiring mandatory equality impact assessments for any new policy proposals. We suggested that the judiciary build on that expertise and apply it to the environmental justice context, strongly recommending that the regulator be called to account annually to show how problems were being dealt with. We recommended a new land and environmental tribunal that would enable the judges to specialize in this complex and growing area of law to assist in counteracting the established judicial culture.

Another major focus for us was the problem of getting the public and government working together more proactively. Environmental justice and good environmental decision making depend on effective public participation. One of the features of the governance relationship that we observed in the course of our investigation was a mutual disaffection between the public and the government. On the one hand, government officials complained that the public was simply not interested; on the other, the public complained that it had been excluded for years, that its views did not count and that there was no point in trying to get involved.

When Peter Hain's government was introducing the water charge proposals the public consultation exercise was truncated by several weeks in order to rush through the new legislation. This led to successful judicial review proceedings being taken by the Consumer Council in Northern Ireland and a period of markedly antagonistic relations between the Council and the Department for Regional Development on this very controversial policy process. We thought this was a good moment to point out the importance of government investment in, and support for, public participation in the whole process of environmental governance.

By way of conclusion it is difficult at this point to say what the future holds for Northern Ireland and the environment. Even though there was perpetual grumbling about direct rule and the need for devolution, our recent experience of direct rule was actually very positive with regard to the environment. Peter Hain introduced several significant improvements, not least a Sustainable Development Strategy that showed a real appetite for change. But there is a definite sense that the newly restored devolved government is at best ambivalent about the issue of the environment. As I said, our report was commissioned by Peter Hain's administration, and then presented to Arlene Foster as new DUP Minister for



the Environment. Several months have now passed since the launch and Arlene Foster's department has as yet made no commitment concerning any aspect of the report one way or the other.

The DUP is first and foremost a Unionist party, and therefore unlikely to be receptive to a cross-border agenda. At the same time, however, we have been witnessing unprecedented levels of cordiality between the principal northern and southern politicians, so anything is possible. The DUP is also a party with a largely rural constituency, and farmers are vehemently against an independent environment agency and many of the changes that have been suggested. They see the environmental agenda as 'anti-progress' and are suspicious that it might even be designed to hold them back. So the DUP as holder of the environment portfolio and dominant political party in Northern Ireland was not a particularly promising backdrop to the launch of our report.

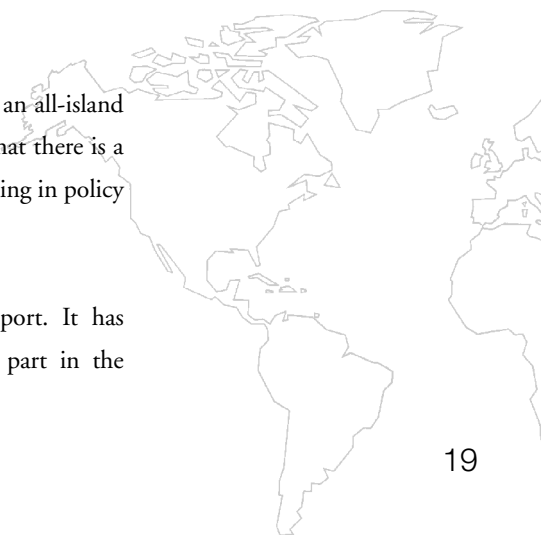
On a brighter note, all the other key players have received the report positively and manifested a tremendous appetite for reform.

The Assembly Environment Committee invited us to meet it shortly after the report was published and has committed to making the report's implementation one of its priorities for the coming term.

The North South Ministerial Council, one of the major organs created under the Good Friday Agreement intended to harmonize relations between the Irish and Northern Ireland governments, has signalled a positive response and shown particular interest in how the environment might be a focus for all-island governance in a particular range of fields.

Sinn Féin is extremely keen to have not only an environmental protection agency but an all-island one – which is probably premature given the current political climate, but it does show that there is a good deal of support for an all-island expert body reporting to both governments and assisting in policy development.

The Northern Ireland judiciary has also come out strongly in favour of our report. It has commissioned a series of training exercises for the judiciary and is keen to play its part in the government process.



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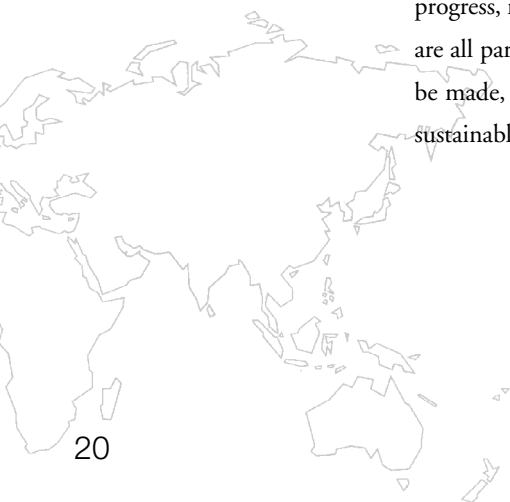
The Northern Ireland Strategic Investment Board, a non-departmental public body tasked with spending public money on major infrastructure and public services, has also signalled a positive response and it too wishes to be involved in the debate. It is about to publish the new investment plan for the region and wishes to align it with many of our recommendations.

Northern Ireland's Criminal Justice Inspectorate also supports a number of our key recommendations. Shortly after the publication of our report the Inspectorate published its own serious indictment of the lack of enforcement of planning and environmental controls, expressing deep concern, in particular, about the loss to our economy resulting from ex-paramilitary involvement in environmental crime, and called trenchantly for immediate reform.

At the same time, politics in the Republic of Ireland is changing. For the first time ever, the Green Party in Ireland now has two Irish ministers: one in the Department of the Environment and one in Energy. So where Ian Paisley and many northern politicians once looked enviously across the Irish border at its tiger economy, they now see an economy that, while undoubtedly facing a slow down, has two Green ministers raising difficult questions about the endemic neglect of the Irish environment. Northern politicians are starting to hear a different voice from south of the border, and this may help to temper DUP's apparent wish to catch up as quickly as possible regardless of environmental issues. Sinn Féin, for its part, is very focused on a social justice agenda.

In many ways the job for people like myself, the NGOs, and all who are concerned with our progress, is to persuade local politicians that social justice, economic viability and environmental quality are all part of the same debate; and while environmental protection will require some hard decisions to be made, failure to face these challenges will seriously threaten Northern Ireland's ability to embrace a sustainable future.

Professor Sharon Turner
Chair of Environmental Law, Queen's University, Belfast



Travelling first class on the Titanic

January 2008

Barbara Young



Environment on the Edge

I always like to quote Sir Crispin Tickell when he was Ambassador to the United Nations: 'If we are travelling on the Titanic perhaps we should all go first class.' Well, I doubt if he really feels we should party our way to disaster (he is, of course, a good environmentalist), but he raised an important point. I would like to outline why, in fact, the option of us all travelling first class simply does not exist. I shall not talk about climate change per se because I think most people are pretty convinced – as indeed are 99 per cent of the scientific community. Climate change is real, human-influenced and, indeed, is already beginning to show some effects.

The theory that I would like to put forward is also largely accepted, and that is that even if we were to stop greenhouse gas emissions now, there is enough carbon dioxide and other greenhouse gases already out there to have serious consequences for the way in which we live. There has been an increasing focus – political, public and in scientific policy terms – on the issue of reducing emissions. But there has been rather less on our need to adapt, so I would like to concentrate on some of the major impacts of climate change in the United Kingdom and how we need to think ahead.

The UK Environment Agency has a particular interest in three major water-related areas: scarcity driven by an increasingly warm climate, which stimulates greater demand for water both inland and in coastal areas; flood risk driven by changed weather patterns and sea-level rise; and the consequences of local and global temperature change for freshwater species and habitats. In addition, there is an overall concern that these and other effects are likely to hit those in the United Kingdom who are least able to cope.

Let's start with the basic resource. The most recent research has confirmed that greenhouse gas emissions are resulting in increased rainfall in and around Europe. There has been a significant rise in mean precipitation in the United Kingdom during the winter months as well as more intense rain. The UK Climate Change Programme has established that by the 2080s winters are likely to be as much as 30 per cent wetter than the norm, especially in some regions. At the same time, summers will be up to 50 per cent drier, particularly in the south and the east. So though we do not expect to see a huge change in overall annual rainfall, shifts in seasonal weather patterns are going to be critical.

We are also likely to see more intense events, with rain falling faster and more water running off to be lost as floodwater, with the accompanying problems of pollution and erosion. Strangely enough, flooding



at certain times will compound the problems of drought at others, as faster run-off also means that our aquifers will be less effectively recharged. There will also be big changes in some of our river flows, with impacts on both the availability and quality of water for human use as well as on biodiversity. Those effects will be very particular to individual regions. Rivers form differently depending on how and where they flow, so it is only on a catchment basis that some of the impacts can be predicted.

At the same time as having a change in the availability of water we are going to see increased pressures on water. On average, domestic water use in the United Kingdom is now 150 litres of water per capita per day. In addition to overall population growth, we are also in that strange state that Michael Meacher once described as ‘refugees from marriage’. There are more single-person households than ever before and, of course, people in single-person households use more water individually than they would collectively. As we get richer, we take more showers, and often have power showers; we have bigger baths; and we water our gardens and fill our swimming pools. The per capita demand for water thus rose by 11 per cent between 1992 and 2003 – a pretty steep rise at a time when we have been increasingly short of water.

It is very likely that the UK population will continue to grow with the effects of climate change, putting ever greater demand on resources. This is a difficult issue to raise – even if you are known to be a good non-racist liberal. The idea of limiting the population is hotly political, and the minute anyone questions whether there is an ecological limit to human numbers in these tightly packed isles, other pieces of political philosophy that are far from liberal come into play. So population growth is something of a minefield in terms of the availability of natural resources – with water being one of them.

Like it or not, if we do see greater desertification and an increase in the barren zones of the tropical and sub-tropical parts of the world – as indeed is expected – the pressure on people to drift further north and further south is quite intense. One of the biggest issues for the future in terms of environmental pressure is just what level of population can be accommodated here. Of course there is plenty of room in Aberdeenshire, and it may indeed be that climate change is the only thing that would make Aberdeenshire comfortably inhabitable. But most of the people who come to live in Britain show little interest in moving to the north, preferring to settle in the midlands and the southeast. So we are going to have some geographically differential pressures.



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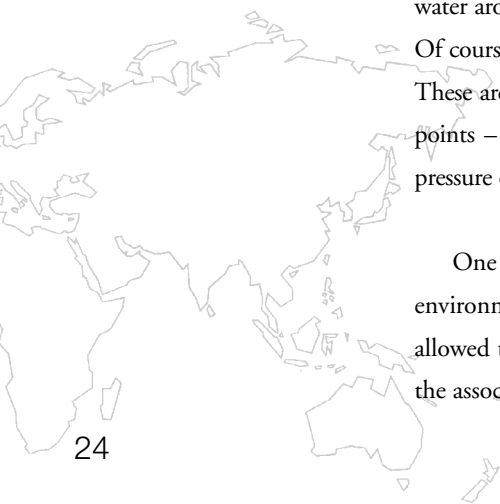
As we said, consumption is increasing and almost half of all water abstractions are for public use. About 55 per cent of that is sensibly used in a domestic setting and about a third is effectively flushed down the lavatory. But there are also peak-time issues. Domestic use can double or even treble during the hotter months, while water for agriculture goes from a small to a very large proportion of overall demand in the summer, just at a time when there is least water around.

It is quite difficult to have a conversation with members of the public about reducing their demand for water because they immediately ask why they are being pressurized into using it more efficiently when the water companies' leakage rates are so high. And there is some truth in this – 40 litres per property per day, or more than a quarter of an individual's daily consumption, is lost in leakage. So there are issues not only in how domestic water is used but also how water providers are going to take action to become more efficient.

The UK Department for Environment, Food and Rural Affairs (Defra) has looked at what the impact of climate change on water use will be if nothing is done to restrain demand. By the 2050s we could see the requirement for agriculture going up by 25 per cent as the need for irrigation intensifies; we could see further increases in domestic demand (in spite of our already high level of use) of as much as 4 per cent; and there is a predicted increase of 6 per cent for industry and commerce, even though these sectors have made considerable progress in water efficiency over the last two decades.

So the demand for water is continuing to rise at a time when there is going to be rather less usable water around. Already, some parts of the country have lower water availability per person than in Sudan. Of course all this is further complicated by ongoing development, particularly in the south and the east. These are the most water-stressed regions of the United Kingdom, as well as the country's major growth points – both traditional and with an eye to creating ecotowns. So development is going to put huge pressure on our already stressed water systems.

One of the tasks that we are currently undertaking with the government is to predict the environmental impact of all these new developments in order to determine where they should be allowed to go ahead, and where there should be measures to control water demand and thereby avoid the associated infrastructure.



The pressure of 3 million new homes by 2020 will put very big demands on water supply, and the solution requires a twin-track approach. One side involves demand management, while the other is about developing new water resources, all of which needs a long-term planning framework. We currently have statutory 25-year water plans coming forward from water companies, but we now need to anticipate much longer time frames of 50 or even 75 years, because that is the sort of period that will see climate change play out. We need to start preparing now, and we need to take account of demographics and development alongside climate change impacts. Of course any measures that seek to satisfy water demand must also look at their own contribution to climate change. Many improvements in both water supply and water purification treatment result in heavier energy use, and there is absolutely no point in bringing more water 'on tap' at the cost of emitting substantial amounts of carbon that will exacerbate the climate problem.

All of that makes the efficiency of the way in which we use water even more important. The more intelligently we use it, the easier it is both to supply and to treat, and the less carbon intensive it is in terms of piping, pumping and so on.

Now let me just talk about demand management. It might sound rather abstract, but is really about how each individual actually uses water. The average Londoner uses 160 litres per person per day, and the average Berliner 110 litres per person per day. Yet the average Berliner appears to suffer no greater lack of hygiene than the average Londoner. And if they can do it, then so can we. There are simple ways in which water efficiency could bring our average usage down to the levels of other developed countries.

The Environment Agency estimates that around 50 per cent of planned growth in population and housing in the southeast could be catered for by demand-management measures. First of all we are talking about design, making sure that buildings are not intrinsically water inefficient, with fixtures and fittings that meet regulatory water efficiency standards. I have been struck when going to look at birds of paradise in Papua New Guinea – one of the wettest countries in the world – that all the lavatories there are dual flush. This is because they import them from Australia, which will allow only dual flush installations. Here in the southeast of England, however, which is a severely water-stressed area, there is absolutely no statutory requirement for water-efficient systems at DIY outlets or through plumbers. The government has now acknowledged that we cannot go on like this, so we hope to see ambitious new standards for water-using appliances as well as an improvement in the standards of fixtures and fittings required by building



regulations. At present, the government strategy for all new homes sets a level of 125 litres of water per person per day as regulatory, but this also needs to be tightened up considerably.

There are other ways of reducing water demand. Metering can reduce total domestic water use by between 10 and 15 per cent, with a considerably larger reduction of around 20 per cent during peak demand. If such a reduction were achieved, all of the new reservoirs currently proposed by the water companies would come under serious question. Perhaps they are not required at all. The Environment Agency is currently consulting on designating a whole range of water-stressed areas in the south and east of England for compulsory metering over the next 10 years. Such measures mean we could start to see these savings being achieved.

An educated public can also do a great deal to help. Simple things like turning off the tap while washing your hands, or not letting your teenage daughter spend 45 minutes in the shower, can make a huge difference. It is of course highly commendable if you also siphon your bath water into the garden.

The Agency has been examining what water neutrality would look like in the Thames Gateway, one of the drier parts of the country, if the planned housing developments take place. We are expecting 120,000 new homes in the area over the coming years, and it would not be unreasonable to set the challenge of achieving that level of construction without increasing water demand at all. That means building the new houses in a very water-efficient way, but also ensuring that measures are put into the area's existing housing stock to reduce demand. There are various options, such as obliging the developers to retrofit existing stock while installing the most efficient possible systems in the new build. If we can do this in the Gateway, we can learn a considerable amount about how to tackle the countrywide problem of water inefficiency in our existing housing stock. The retrofit could be fairly simple, for example low-flow showerheads and taps, and dual flush systems. Manufacturers of fixtures and fittings are at long last recognizing that they are going to have to be quite innovative in looking at new ways of bringing forward water efficiency.

Water efficiency can go a long way to alleviating the problem, but we also need to look at the resource itself. Essex and Suffolk Water is hoping to extend one of its reservoirs; Thames Water would like to build a completely new reservoir in Oxfordshire. But the Agency is not wholly enthusiastic about this. We really

want to use water scarcity as a driver for water efficiency before further disrupting water flows and habitats. I am always slightly jaundiced when water companies tell me that reservoirs are good for ducks, because, as many of the ornithologists here could also tell you, we are not short of ducks in this country. There are other things that we are more short of. So the twin-track approach is genuinely a means to a track, not just an excuse to build more reservoirs. And let's not build desalination plants either, because they are incredibly heavy in energy as well as in effluents.

I would now like to turn to flooding. Just at a time when we worry about not having enough water, we suddenly discover that we've got too much. I once got the Guardian award for the most ridiculous remark of the year: the accolade came when I launched a water-saving campaign while standing up to the waist in ice-cold water in my waders during a flood. We did it deliberately because we knew it was the only way to get coverage – and it certainly worked.

Both the underlying risk and the costs of flooding are on the rise, with the rate of insurance claims increasing by about 2 to 4 per cent per annum. This is expected to persist as climate change continues to bite. The government-sponsored foresight study calculated that annual flood damage would rise from £1.4 billion, the average in 2002, to over £20 billion in 2080 in a 'business-as-usual' scenario. The number of people at risk of flooding will rise from 1.5 million to 3.5 million. The next flood risk assessment, which will take place following the 2008 publication of the UK climate impact predictions, will take full account of those predictions and may well produce a much gloomier picture.

We are currently building allowances for climate change into the flood defence measures of the riverine environment, but these measures only anticipate the average effects of climate change – not the very great extremes that we are now beginning to see. Meanwhile, climate change impacts on the coast are compounded by the way in which the land is dropping. Sea-level rise is already under way, with around a metre of rise expected by the end of the century. And we are seeing increased coastal storm surges. In November 2007, areas of pressure produced a great dome of water channelling down the North Sea, funnelling up the estuaries and threatening eastern towns such as Great Yarmouth and Ipswich, and coming within a hair's breadth of overtopping our sea defences. The combination of sea-level rise, coastal deterioration and storm surge is now threatening a very major flood on the east coast, where erosion is at its worst.



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At the moment we have about 100,000 properties – worth £130 billion – at risk of coastal flooding, so there is a major need for adaptation even under moderate predictions of sea-level rise. Add to that the fact that we are also getting wealthier, and the annual economic damage could be as much as a quarter of a per cent of GDP by the 2080s. That would be a two- to four-fold increase on the losses that we saw in the summer floods of 2007, and we can expect it to happen every year, so it is really quite serious.

Issues related to floods impacts are multiple. The highest-risk floodplain in the United Kingdom carries an average risk of flood once in 75 years, and communities can cope with this, but to be flooded out twice in as many weeks – as happened last summer around Tewkesbury – is disastrous. The water treatment plant went under water, leaving many with no supply for quite some time, and the electricity substation almost went the same way. Now had it done so, I think we might have seen the government fall. Some 750,000 people would have been without energy for more than two weeks. This time it didn't happen, but the flood was severe enough for people to begin to think about what it might mean. We rely so heavily on electronic instruments for our daily lives and work that practically nothing of importance happens without electricity. If it becomes unavailable for extended periods our entire support system collapses. And of course it is not just about power and water: railways and roads, hospitals, old peoples' homes and care homes, schools and food outlets all cease to function. So we need to make sure that those who have responsibility for running such establishments take climate change into account, think about the long-term future and start putting adaptation measures in place. Of course heat can be as much of a problem for our power infrastructure as floods. Most of our electricity substations would cease to function under sustained summer temperatures of 31°C, and we are not far from experiencing such temperatures. So our infrastructure providers need to address the problem with both flood and heat in mind.

Adaptation measures also have to take account of the variability of rainfall. Summer is now seeing increasingly intense bursts of rain concentrated in small areas, while winter is more prone to steady and widespread rain over longer periods. One might see sudden flood from above-average run-off; the other might see rivers and reservoirs gradually filling beyond their capacity. Each can cause floods.

Surface-water run-off is a key issue that nobody seems to want to deal with, partly because of the many factors involved. After a heavy downpour, it runs off the roads in torrents if these are badly planned; it pours off farmlands if these have not been managed and tilled in ways that hold water back; it can come



up from the sewers that belong to the water company; it runs out of people's driveways; and of course rapidly overloaded rivers can burst their banks, so the Environment Agency is responsible too.

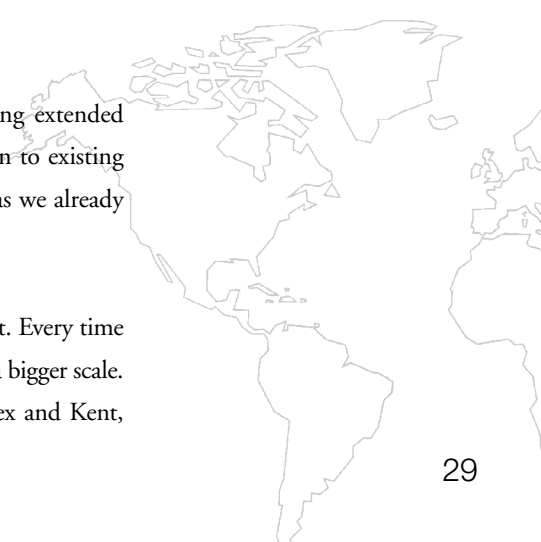
We currently have a Climate Change Bill going through the House of Lords that aims to put greater focus on adapting to climate change rather than just measures for reducing greenhouse gas emissions. This would impose a statutory duty on the providers of critical infrastructure to take climate change into account in their plans for the future. Government recognizes that this is a real issue, and the Agency is being given a major role in fully coordinating all involved. This will require working on a local basis with all relevant organizations: urban planners; road builders; water companies and sewerage works; and the agricultural sector.

The Mayor of London worked out that an area eight times the size of Hyde Park has been paved over by people putting tarmac on their front gardens because they need to park their cars somewhere to avoid congestion charges. The congestion charge is an extremely good idea in carbon terms, but the downside is an increased risk of flooding as people seek to avoid it. We shall have to think very inclusively to take such things into account.

Sustainable urban drainage systems (known as SUDS) will involve more porous surfaces that reduce water flow and harvest rainwater for other purposes. The provision of ponds, lakes and wetlands in city areas can also facilitate drainage and slow the water's route to overloaded rivers. There are plenty of possibilities, but they will all need maintenance in the future and it is unclear who will take ownership and responsibility.

We also need longer-term plans for our sewerage systems, as currently they are being extended beyond their capacity. At present, any new developments just add more sewerage pipes on to existing Victorian infrastructures. But we need 25-year forward planning for our wastewater just as we already have for our freshwater supply.

Short-term solutions aren't a solution. Take, for example, the Thames flood embankment. Every time there has been a major flood in London there has been a decision to rebuild the defences on a bigger scale. As recently as the 1953 floods, when there was huge loss of life along the Thames in Essex and Kent,



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additions were made to the flood embankment. But we cannot just continue building walls, as very shortly you will not be able to see the river at all. And, of course, if an enormous surge does pour over the top of a large defence, it will do even more damage to an area than if there had been no defence at all.

We need to take a much more holistic approach in the way we manage estuaries and catchments so that the land itself can be used for water storage. We are looking at a wide variety of solutions for protecting the banks of the Thames. Some strengthening of defences is expected, but over the next three or four decades we also plan to provide very large-scale wetlands in the outer Thames. These will have a variety of functions including supporting biodiversity and providing for recreation, and when a really big flood occurs they can also be allowed to fill up with water – a much more successful way of reducing flood risk in London than building huge concrete barriers across our estuaries.

There are two more issues to take into account with the question of increasing flood risk – putting things in the wrong place or designing them in the wrong way. Take, for example, the caravan park at Hunstanton, which is home to largely retired elderly people and particularly prone to flooding. This is quite simply the wrong place for elderly people to live. If we have to carry the old ladies of Hunstanton Caravan Park out of their homes one more time I think they will go crazy.

We need to make sure that strategic processes are applied to ensure the right location for a particular development. Regional authorities must use strategic flood risk assessments in order to make individual development control decisions, and only permit development in a floodplain if all other avenues have been exhausted and if the development itself is not going to create additional flood risk.

It is fair to say that the majority of local authorities make responsible decisions about the location of new developments. But there are still a few rogues who seem intent on building things in the wrong place. One that instantly comes to mind is Lincoln City Council, which wants to build 6,000 houses on a site called Swamp Pool. I think there is a bit of a clue in the title.

On the coast we have big challenges, and increasing pressure to find innovative ways of looking at risk management. Here it is a case of using rising ground as a natural defence and wetland habitats as a means of buffering the sea. A programme on 'Making Space for Water' that we are currently running with Defra

provides some answers, even though it is still very small scale. A number of demonstration sites have been created around the coast, where salt marshes have been recreated to function alongside coastal retreat programmes. It is on this type of solution that we should increasingly be focusing, making the best possible use of natural ecosystem services rather than just trying to block the forces of nature. The decision to abandon coastland is not an easy one. Suffolk MP, John Gummer, has said that for as long as he is an MP no English soil will be under water. King Canute? I rest my case.

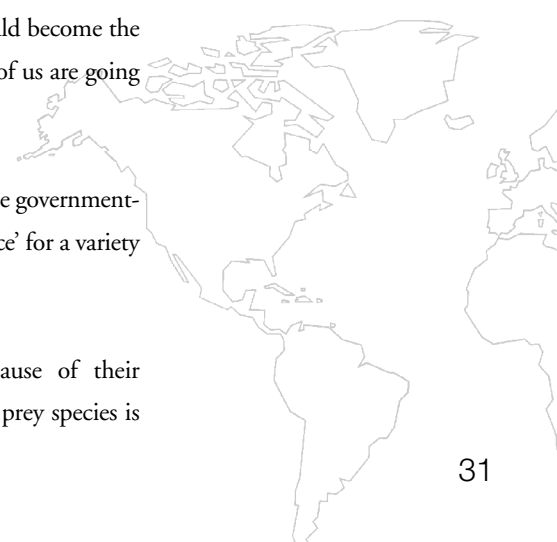
In reality the sea is making its own decisions. There are settlements at the Blythe Estuary that it will simply not be possible to protect, either economically or practically. Very few communities are comfortable with that thought, but we hope that by giving them a reasonably long time horizon to adapt, they will develop strategies to move back from the coast. Some in fact are already making plans. Mablethorpe in Lincolnshire has recognized that the first two streets running along the coast are simply not defensible, and are planning developments back from the sea and up the hill.

Let us go back to 'travelling first class on the Titanic'. Climate change will not affect all parts of the UK population equally. The poor inevitably come off worst, as many are underinsured or not insured at all. A stunning 90 per cent of the people who suffered flood damage in Hull last summer had no insurance; in excess of 10,000 people lost everything.

And of course climate change is not just about water issues. Certain groups are more at risk during heat waves, particularly older people, babies, and people with heart conditions or respiratory problems. The summer of 2003 resulted in 2,000 extra deaths, yet the temperatures that caused them could become the norm by the 2050s, and by the 2080s might even be considered cool. I do not think any of us are going to be able to travel first class.

Let me just finish with species because we are not the only ones who will be affected. The government-sponsored Monarch report maps the changes we might expect to what is called 'climate space' for a variety of our species.

We have much to learn about what happens to assemblages of species, because of their interdependency. There may theoretically be climate space for a certain species, but if its prey species is



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not available at critical points of its breeding or feeding cycles it will not be able to raise its young. Some – including certain birds and butterflies – are capable of moving, but others are more sedentary. We need to create environments that give these species the greatest possible opportunity to move as and where they need to, including conservation landscapes and large tracts of land that enable them to adapt. We also need to learn to spot the species that are going to be in deeper trouble and decide whether we can do translocations. This involves the establishment of captive breeding populations to make sure that they do not die out.

New coastal habitats must be created to replace those lost through coastal squeeze. Some are already under way: 4,000 hectares of standard arable farmland between Huntingdon and Peterborough, for example, is being purchased by a consortium of partners to create a big new fenland in Cambridgeshire. This will join up two small remnant areas of fen, bringing true fenland back to this part of the world for the first time in a long while. I am really pleased to be on the fundraising committee.

Last but not least, a word about our sponsors, the government. At long last the government has got the message that all this adaptation stuff is pretty important, and is going to draw up a national adaptation programme. Two particular things are needed. One is the Climate Change Bill, which will firmly establish the national adaptation programme so that mechanisms are in place to determine the respective responsibilities of infrastructure and service providers. The second is an independent adaptation scrutiny committee. The government is currently working on a climate change committee to scrutinize emissions reductions programmes, and adaptation to climate change impacts is sufficiently important to necessitate something similar. We know that our efforts to reduce carbon dioxide and other greenhouse gas emissions are way off track, something of which the government is well aware, but this makes the imperative for adaptation even greater. We need to go further and faster.

We do not have the option of choosing first class or steerage. The reality is that we are in this together and the impact is going to hit us all. We have got to work to reduce emissions at the same time as taking account of the need to adapt. If we do a good job on reducing emissions the impacts will be lessened, but some are unavoidable, and we must be ready for them.

Barbara Young, Chief Executive of the UK Environment Agency

The economics of climate change

February 2008

Lord Adair Turner



Environment on the Edge

GDP and cost codes may not have the immediate appeal of melting glaciers and polar bears, but it is the process of economic growth and industrialization that has actually created the challenge of climate change. So it is important to think about the economics of climate change in order to find a path to mitigation that will be acceptable to people and at a reasonable cost. I am therefore going to concentrate primarily on economics, but I want to start with one or two quick comments on the science.

I want to look at the correlation over time between the two categories of greenhouse gas – carbon dioxide and methane – and global temperatures. Ice core records for the last 450,000 years show almost identical patterns of rise and fall in greenhouse gases and temperatures, with surges followed by more gradual stepped declines. But, as climate change sceptics legitimately point out, they are not quite simultaneous: temperature starts to rise just before the CO₂ and methane concentrations. What sets off the rise is almost certainly variations in the intensity of solar radiation due to certain features of our orbit around the sun, and the sceptics use these data to dismiss theorists who say that carbon levels drive temperature change.

The fact that the almost simultaneous growth pattern in CO₂ and temperature is started by a shift in temperature should not, however, be a cause for reassurance. Movements in both temperature and greenhouse gas emissions are far larger than can be explained by the original stimulus of variations in radiation. What is actually going on is that a small exogenous stimulus is then being amplified by a set of effects which are internal to the climate process, with hugely magnified results.

Over the last century or so, a large exogenous anthropogenic input has pushed levels of atmospheric greenhouse gases way beyond the historical pattern. We are not just on the edge but beyond it, breaking out of at least half a million years of historical variation.

Indeed we are going back to levels of CO₂ and greenhouse gases that have not been seen for 10 or 20 million years. What is really interesting in the long-term paleoclimatology record is that if you go back 60 million years, the levels of CO₂ in the atmosphere are massively higher than they are at the moment. There seems to have been a process spanning 50 million years when atmospheric CO₂ essentially left the atmosphere and ended up as fossil fuel.

What we are now doing is putting fossilized carbon back into the atmosphere as CO₂. If we continue with business as usual and release all the stored carbon that we know to exist, in particular the coal, we will release about 5,000 gigatonnes of carbon, which could easily drive total concentrations of CO₂ in the atmosphere not just to 600 or 700 parts per million (ppm) but way up to 1,500 or 2,000. It would take us a couple more hundred years to get there, but that gives us an idea of the scale of what we are doing. Its impact on temperature would probably take thousands of years to work through rather than just centuries. We would return to a dramatically different climate.

There have been very big temperature declines over the past 50 million years, in the region of 8 or 10°C. When all that carbon was in the atmosphere rather than in fossil fuels there were no polar ice sheets. The sceptics are absolutely right to say that the historical record does not show a stable climate, but it is precisely the variability of the past climate that should worry us when we think about the future. One of the complexities of the science and economics of climate change is that we frankly do not know how they will play out once the feedback loops have produced an effect.

Depending on where we are in the range of scenarios laid out by the Intergovernmental Panel on Climate Change (IPCC), our burning of fossil fuels could take the global average temperature to somewhere between 2 and 6 degrees higher than the pre-industrial level by the end of the century. As Professor John P. Holdren at Harvard University has said, 'continuation of recent trends... leads by 2100 to temperatures not reached since the Eocene (25-35 million years ago), when sea level was 20 to 30 metres higher.

Now because of the inertia in the system, it takes an extremely long time for sea levels to adjust to atmospheric temperature increases. So it is reasonable to say that if we take a long approach to this – rather than that of my colleagues in the financial services industry who consider the long term as about a year – we have an environment on the edge.

So what has all this to do with economics and growth? Does it mean that we have to give up the idea of material prosperity, growth and consumption? Is the crisis such that there is no point in running fancy economic models? I do not think so, either in terms of the economic analysis or in terms of the implications for growth. Firstly, economics has quite a lot to tell us about how we should respond and



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the most cost-effective ways of doing so. Secondly, I do not actually believe that significantly mitigating climate change will require us to give up the benefits of material prosperity. The sacrifice needed is in fact quite slight.

It is almost impossible now to stop the world's climate going up by 2°C, maybe even 2.5°C. We have released such quantities of a number of greenhouse gases that there is no reverse gear. The debate now is about what action we can take to ensure that temperatures do not rise by 4 or 5°C. The economics of climate change really matters.

What exactly is the economics of climate change? An economist would summarize it thus: compare through time the economic and social cost of climate change and assign an economic value to its adverse consequences; identify the costs of mitigating climate change; identify the costs of adapting to climate change because we might choose to adapt rather than mitigate; and, of course, maximize net present value. We maximize the net present value of human welfare by taking into account the changing pattern of costs through time and using an appropriate discount rate to compare the value of different people's welfare at different points in time. That is the economics of climate change, which turns out to be a rather difficult thing to do.

There are many economists who have tried to cover all sides of the problem using what are called integrated assessment models. These take all the different costs at different periods of time and plug in discount rates, and come up with a result. One of the problems with this type of modelling is that it is so complicated that it's hard to know how to respond to the results. There are so many assumptions written into every line of the model that you cannot actually get a handle on whether the assumptions are sufficiently robust to be meaningful. It is a very complex challenge.

First you have to establish what our emissions of greenhouse gases will be as we go into the future. For this, you have to estimate GDP growth, the energy intensity of GDP growth, and the carbon intensity of energy. These are the scenarios for emissions and this is where economists play an important role. Then you have to turn emissions into stocks of greenhouse gases in the atmosphere, which is actually one of the easiest steps because it involves the straightforward physics of the dissipation of gases in the atmosphere. What is really tricky is working out whether 350ppm of



atmospheric carbon – or 400 or 500ppm – relates to a particular temperature level. That theory has huge uncertainties.

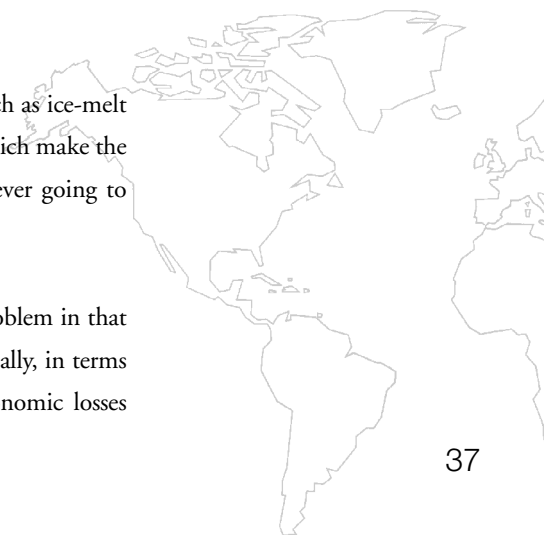
Then you need to go from the average global temperature to regional climates and anticipate what is going to happen to temperatures and rainfall in particular areas. That is even trickier, but you need to get to that point in the calculations before you can begin to identify the economic and social consequences. What does it mean for crop yields, for peoples' health or for their way of life?

The relationships between atmospheric carbon and global temperature are non-linear, and we do not currently have – I suspect never shall have – absolute certainty about exactly what level of cumulative atmospheric carbon will produce what global temperature. What we do have is uncertain probability. The best the scientists can do is give us probability distributions of the likely concentration of CO₂ at which we must stabilize if we are to avoid going above a certain rise in temperature. The Hadley Centre has calculated that if we stabilize at 550ppm we have a 99 per cent probability of a temperature increase greater than 2°C but only a 24 per cent probability of an increase greater than 4°C.

We have to realize that we are always going to be dealing with a famous distinction made by Frank Knight, the well-known economist, between uncertainty and risk. We are not dealing with a precisely modellable risk where we can say definitively that the probability distribution results are XYZ. What we have is an uncertain judgement as to what a probability distribution is, and that is a tricky thing to deal with when you are trying to optimize your course of action. In terms of anthropogenic greenhouse gas emissions, it means that the effect on temperature can only ever be uncertain.

One thing we can be fairly sure of is that due to amplifications within the science (such as ice-melt reducing the planet's albedo, which in turn increases ice-melt), there are feedback loops which make the relationship between our emissions and the climate's response non-linear. But we are never going to know precisely what that non-linear function is.

When we think about the adverse social consequences of climate change we have a problem in that they come in many different categories. Some are quite easy to work out, at least conceptually, in terms of GDP equivalent – for example the cost of building a flood defence system, the economic losses



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associated with changes in crop yield, or the cost of three times the usual number of hurricanes. Others, however, require a value judgement – for example the value of human welfare when it comes to heat waves, the spread of tropical diseases or coastal zones going under water. It is the conceptually ‘containable’ effects that can be – and have been – put through integrated assessment models by economists. The bigger impacts are much harder to assess.

Then there are what are called contingent effects, which are incredibly difficult to value. If the regional effect of global warming is to lead to a sudden movement in the Sahara desert, producing lower agricultural yields in places like Niger, then you have increased poverty. The net overall effect of that both on measured GDP and on human welfare could be massively higher than what you would anticipate simply looking at agricultural yields.

Finally, you have entirely subjective judgements such as the aesthetic or spiritual value of species and the landscape itself. One of the reasons why economists produce hugely varying estimates when trying to work out the costs of climate change (Sir Nicholas Stern said as much as 20 per cent of GDP; William Nordhaus said as low as 1 or 2 per cent), is the difficulty of where the cut-off point lies across these different categories of effects. Once again, we have non-linearity. A 4°C temperature increase would be far more than twice as bad as a 2°C temperature increase. But at what point does the ability to adapt break down, and of what and for whom? If you want to put non-linearity into a model you have to turn it into some sort of equation. Frankly, we are just guessing at what kind of equation can express non-linearity.

We also have a great debate about discount rates. This is a somewhat esoteric issue. The range of debate, which is between a discount rate of 2 per cent and one of 4 per cent, may not sound very big. But the thing about compound interest is that pursued over 150 years the difference between 2 per cent and 4 per cent is transformational. What value should you place today on a £1,000 detriment in 2150? With a 4 per cent real discount it is worth £3.67 today, but with a 2 per cent discount it is worth £59.00 today. So how you trade off the value of the future versus the costs of the present depends very much on the discount rate. Discount rates really are quite fundamental, and it is not surprising that they have been debated.

Finally, in amongst the layers of complexity already outlined, there is a problem in that the impact of climate change almost certainly varies very significantly in different parts of the world. The IPCC’s

Working Group II Report, which sets out the impact of climate change on ecosystems and human life, tells very different stories for different regions. For Africa there are projected reductions in crop yield of – in some countries – as much as 50 per cent by 2020, and crop net revenues falling by as much as 90 per cent by 2100. The population at risk of increased water stress is projected to be between 350 and 600 million by the 2050s. In Europe, however, all we need to worry about is the likelihood that winter floods will increase in coastal zones and that flash floods will increase throughout the region. And winter tourism in mountain regions is expected to face reduced snow cover. Well, we have seen some flooding already and can probably adapt and deal with it. So we are really talking about the trade-off between our skiing holidays being disrupted and quite a lot of people in Africa dying.

If you look at the IPCC's figures for the additional population at risk of hunger in the next 50 years, they expect there to be tens or even hundreds of millions of people at risk in Africa, but none in northwest Europe because even if we had to deal with considerable climate change, we are a rich developed society with some capacity. There are two things going on here. First, the hotter countries are more vulnerable to slight increases in heat. If the temperature in the United Kingdom went up by 3°C it would be a different climate but it would not be an impossible one. In parts of India or Africa another 3°C makes it quite unsuitable for human life.

This means that the economics of climate change is heavily influenced by ethical issues of what relative weight you attach to harm in one country or in another, or indeed to sacrifices that the developed world may have to make versus the harm that the developing world could face.

Sir Nicholas Stern's report concluded that if we do not act, the overall costs and risks of climate change will be equivalent to losing at least 5 per cent of global GDP each year, now and forever. If a wider range of risks and impacts are taken into account, the loss could rise to 20 per cent. In contrast, the cost of actions to reduce greenhouse gas emissions to avoid the worst impacts of climate change are around 1 per cent per annum. I have read Nick's report, and been involved and debated it, and concluded that for all the uncertainties, its overall conclusion is completely robust. A reasonable assessment of the potential damage says it is really very big. Nick's own figures concur that it is inherently difficult to decide whether you place a value of 5 or 20 per cent on the costs of inaction. Either way, it is much bigger than the cost of mitigation, and at least we have a higher degree of



certainty regarding the cost of mitigation – I would argue that a reasonable estimate is around 1 to 2 per cent of GDP.

So, why did Nick Stern conclude that it could be limited to 1 per cent of GDP and, indeed, why is that the figure that most economists who have looked at the challenge come up with? It seems surprisingly small when you think about the scale of the changes that we need to bring about.

If we are to have a chance of stabilizing greenhouse gas concentrations at something like 500 to 550ppm (versus 380 today and 280 in the pre-industrial era), then an appropriate abatement scenario would see emissions peaking in around 2020 and then declining by something like 20 or 30 per cent relative to current levels by 2050. This is 60 to 70 per cent lower than what we might expect in a 'business-as-usual' scenario. Of course these are global figures, so the developed world will have to make even greater emissions cuts to allow – at least for a while – for some growth in the developing world.

China's per capita emissions are currently about half of European levels and about a fifth of US levels. India's are still only an eighth of European levels. The International Energy Agency estimates that China's per capita emissions will double by 2050 to reach current European levels. If we assume that poorer economies are necessarily going to increase their emissions as they grow richer, the challenge for the developed world in any reasonable abatement scenario is to cut its emissions by something like 60 to 80 per cent against the current level. Indeed, in 2000, the UK Royal Commission on Environmental Pollution recommended cutting emissions by 60 per cent by 2050.

This target is also written into the Climate Change Bill set up by the Climate Change Committee, though one of the Committee's current tasks is to report by December 2008 on whether that target should be not 60 per cent but 80 per cent. Some people would say 90 per cent. Either way, running our economy on upwards of 60 per cent less carbon and other greenhouse gases than we currently do sounds like an impossible challenge. But there are good reasons to believe not only that it is technologically feasible, but that it can be done at a manageable economic cost.

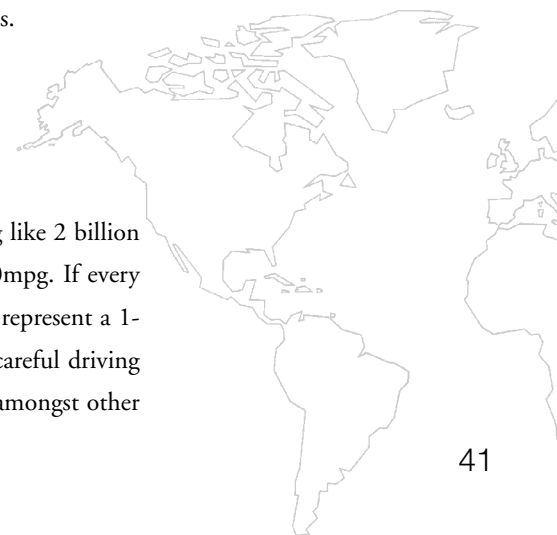
One way to think about technological feasibility is a rather useful analysis presented by Professor Socolow at Princeton University. It is well known as the 'Socolow Wedges'. Total annual carbon

emissions are around 7 gigatonnes (around 25 gigatonnes as carbon dioxide). Under current trends this will rise to 14 gigatonnes by mid-century. To flatten the slope over the coming decades would require removing 7 gigatonnes from the trajectory. But flattening it is not enough; emissions need to begin a downward trend. How can this be made manageable? What Socolow and his team came up with was the idea of imagining every gigatonne on the 50-year trajectory as 'a wedge' – which, indeed, is what it looks like on a simple line graph. They asked what would have to be done to take out a wedge of 1 gigatonne, and compiled a list of actions, each of which can remove a 1-gigatonne wedge using technologies which are not gleams in the eye of scientists in the lab, but – with some exceptions – exist at some cost today:

- Increase fuel economy for 2 billion cars from 30 to 60mpg.
- Decrease travel for 2 billion 30mpg cars from 10,000 to 5,000 miles per year.
- Cut carbon emissions from buildings and appliances by 25 per cent.
- Double the existing capacity of nuclear power.
- Switch natural gas for coal for 1,400 gigawatts of electricity generation.
- Introduce carbon capture and storage (CCS) at 800 gigawatt coal stations.
- Introduce CCS at fossil-based hydrogen plants while increasing capacity 10-fold.
- Introduce CCS at coal-to-synfuels plants producing 30 million barrels per day.
- Increase wind-power capacity 50-fold.
- Increase solar photovoltaic capacity 700-fold.
- Increase the 2004 Brazilian ethanol production 100-fold.
- Reduce deforestation to zero, plus reforestation, afforestation and new plantations.
- Apply conservation tillage to all cropland.

I shall comment on a few of them.

With regard to vehicle fuel efficiency, the middle of this century will see something like 2 billion cars in the world. The business-as-usual assumption is that they will run at around 30mpg. If every single one of them – or the average of all of them – could achieve 60mpg, that would represent a 1-gigatonne emissions saving. This is not impossible. You can buy cars today that with careful driving give you that sort of fuel consumption. One of the great effects of the Toyota Prius – amongst other



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modern cars – is that it gives you a continual count of your fuel consumption, and drivers with counters tend to have a little game with themselves to increase their mpg. With technological progress over the next few years, an average of 60mpg for all cars is an achievable target.

Halving the distances we travel in private vehicles is probably a bit more difficult. But rising fuel costs will have an impact, and urban design focused on efficient mass transport systems brings it into the realms of the possible.

The nuclear issue is probably controversial, but if we triple the present capacity to 1,050 gigawatts, that is another gigatonne of carbon emissions saved. Gas for coal substitution is feasible, at least until we can get real renewables up and running.

Coal is a much dirtier fuel than gas in CO₂ terms, so carbon capture and storage is an absolutely vital technology. Whether we like it or not, the Chinese are building huge numbers of coal-fired power stations, so unless we develop and make economic the technology to capture that carbon and store it in geological strata, we are not going to succeed.

We need 50 times as much wind power as at present. That is a huge task, but not impossible. This is true of pretty well all of the actions suggested above.

I think that there are two main conclusions to draw from this list. First of all, it is feasible. Second, it has to be a combination of these things: you cannot just bank on one.

You might be in favour of nuclear power and happy to treble current capacity, but you cannot multiply that up to solve the problem because you will run out of uranium. As stated, 50 times as much wind power is doable, but try covering all our energy needs with wind power and you will run out of places to put windmills. Biomass may have a contribution to make, but if you try to do the whole thing with biofuel – unless we get real breakthroughs in technology that allow us to grow biomass in desert areas or new ways of producing it in laboratories – it will be at the expense of food production. Indeed, half of what is going on in food prices at the moment throughout the world is the competition from bioethanol, unfortunately produced in an incredibly environmentally unsustainable fashion as a result

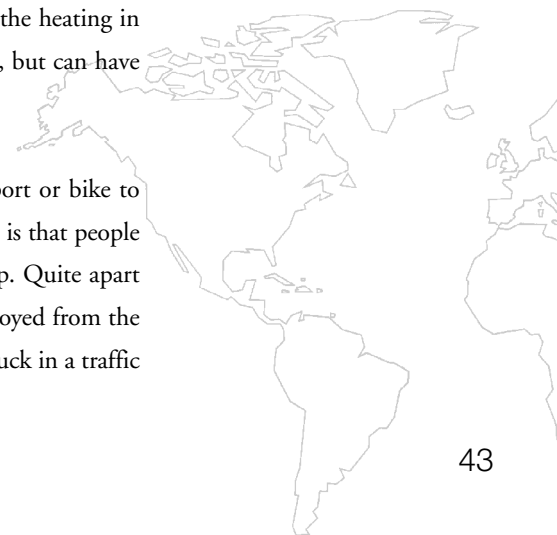
of the American subsidy regime. This may have started as an environmental proposition, but it has turned into yet another way to make Iowan farmers significantly richer. Iowa, of course, has a rather large role in the American electoral system because it holds its caucuses before anyone else.

The list is feasible, but it does not tell us anything about the costs. Do all these carbon savings cost far too much for the economy to absorb? Actually, the answer is no. All the best analyses say that doing a mix of these or other actions is much more likely to be 1 or 2 per cent of GDP than 5, 6, 7 or 8. I would argue that even if it were 5, 6, 7 or 8 – or even 20 – we should still do it. Fortunately, that does not seem to be necessary.

To put 1 to 2 per cent of UK GDP in context, it is somewhere in the region of £14 to 28 billion. Over the next 50 years, on the UK Treasury's medium forecast, the country's per capita GDP is likely to go up by about 2.4 times. The cost of a 60 per cent emissions cut is only around 0.3 to 2 per cent of GDP. Now in terms of our rising living standards, this means that rather than achieving the rise we might expect in January 2050 with no emissions cuts, we will have to wait until November of that year. This does not seem a major threat to our material prosperity.

But is it believable? What does it actually mean for people's way of life? Of course lifestyles will have to change, but some of these are at no real cost at all. In fact they might even be positive. Here in the United Kingdom, as well as on my business travels, I continually find that buildings are either overheated or air-conditioned to the point of necessitating an extra layer of clothing. But the choice to standardize temperatures at 18, 20 or 22 degrees is completely arbitrary. Turning down the heating in winter and raising the temperature in summer by a couple of degrees is easy to adapt to, but can have a huge impact on the carbon emissions figures.

Similarly, if people can be persuaded to get out of their cars and take public transport or bike to work there is nil cost. GDP does not go down; incomes do not go down. What happens is that people have more money to spend on other things, and their overall well-being may well go up. Quite apart from the potential benefits to health and fitness, there is a considerable benefit to be enjoyed from the 'smugness factor'. A cyclist cannot help but feel superior as he or she cycles past people stuck in a traffic jam in their SUVs. There is a consumer value in smug superiority.



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There are lots of ways in which we can change our lifestyle that have no measurable effect on GDP but can save a lot of carbon. How many of them we are actually willing to do is one of those tricky questions that cannot really be answered. We on the Climate Change Committee will have to think about what assumptions we can make and how we can model them in.

Moving on from nil-cost emissions savings to nil- to low-cost ones, actual numbers become a bit more accessible. There is a whole set of opportunities in households and companies to improve energy efficiency, such as improving insulation, which might cost a little bit up front, but gives a positive rate of return. The Carbon Trust has estimated that in UK manufacturing, about 10 to 20 per cent of emissions can be cut while giving a return of more than 15 per cent – and of course we can do this at home.

Fluorescent light bulbs may cost four times as much as incandescent ones, but at 11 watts rather than 60, they produce the same amount of lumens while using 80 per cent less electricity. And of course they last much longer, so over three or four years of use there is a positive net value. Now it might seem a bit ‘nerdish’ to spend the evenings calculating the value of investments in light bulbs, but it is only when we do the calculations that we see the opportunities – and there are plenty. One of the things that has to be worked out by the Climate Change Committee is to identify those opportunities, figure out how reliable they are and how they can be achieved.

There are also things that will cost us money. Pretty well all renewable energies that we know about do have a cost penalty over fossil fuels, but for many of them we are talking about a cost penalty of an additional 30 or 40 per cent, not 300 or 400 per cent. It is not prohibitive.

Just look at this simple calculation (sometimes in economics, simple calculations tell you more than complicated integrated assessment models). Total energy costs as a percentage of GDP are now about 4 or 5 per cent. In a business-as-usual scenario, putting aside any impact that energy efficiency measures might have, that will probably fall to 2 or 3 per cent by 2050. Now suppose that energy in a renewable form might cost 50 per cent more, that extra 50 per cent on the cost is actually only an extra 1.5 per cent of GDP. That kind of order-of-magnitude calculation tells us that even if we pursue carbon emissions in a relatively inefficient fashion, it still won't cost all that much.

To run it another way, we can produce gas electricity or nuclear electricity at 3p per kilowatt hour, and onshore wind at around 6p per kilowatt hour. So there is a cost penalty of 3p per kilowatt hour. Our total electricity consumption in the United Kingdom is about 300 to 350 terawatt hours or 300 billion kilowatt hours. Multiply the 3p cost penalty by 300 billion terawatt hours and you get a cost penalty of £9 billion. Expressed as billions of pounds it sounds like an enormous cost, but it is actually only 0.6 per cent of GDP, so not such a great sacrifice of material prosperity.

Overall, I am optimistic that this is doable at reasonable cost, but there is a huge amount of work if the Climate Change Committee and government are actually to deliver it. I have set out an optimistic picture of the economic feasibility; pulling the policy levers to make it happen is a bit more complicated.

I have already mentioned emissions mitigation measures that economists have worked out to be at zero net cost, such as additional insulation in buildings, low fuel consumption vehicles and the like – all of which are basically energy efficiency measures. These are things that fall below the x axis on a cost curve. They don't need carbon tax incentives, because they are enough of an incentive in themselves. But if they are positive NPV (net present value) projects, why have they not been done already?

It was once said that if an economist sees a £10 note on the street, he/she will not pick it up because if it were genuine it would have been picked up already. These projects have not been grasped because there is a hidden cost in actually thinking about them. Thinking about them is in itself a cost. If, for example, you are refurbishing your house, you might want to install energy-efficient light bulbs or additional insulation or triple glazing, but your builder will probably roll his eyes at you because it's not what he usually does. So you don't get round to it.

There is a paradox here in that one of the biggest problems is just how cheap energy is. The main reason that people replace incandescents with fluorescents is not that they have done the calculations; it is because they feel that it is better for the environment. It is an ethical decision. Energy is so cheap that we are not forced to count every penny that we spend on it and figure out how to make savings. For those of middle income and above, electricity consumption is not a big part of the household budget, and small savings are of little interest. You might as well just have a glass of wine and a relaxed evening rather than do the calculations.

This is also true of the commercial sector. If you are running a large commercial building like an office site in Central London, the energy inputs to running the business are 4 per cent or even less of your total costs. In some industries, like chemicals, steel or aluminium, energy inputs are such a large proportion of the total cost of production that professional managers will have seized all the opportunities to squeeze out extra energy efficiency. Even then, they will have concentrated on the production process, not on the relatively very small costs of running their offices. There are plenty of commercial businesses, both large and small, with so many other things to worry about that positive NPV energy projects get ignored amongst the general pressures.

In terms of the complexities of switching to renewable energy, one of the challenges here is to work out the cost penalty, and the key difficulty is that the cost penalty is not an exogenous given. It is in itself an endogenous given affected by public policies. The cost of moving, for instance, to wind power – whether onshore or offshore – or tidal power is crucially dependant on how fast we choose to make the change, because the costs are determined by a different form of cost curve. It is a ‘decline with experience’ curve, where in many technologies the more that you produce of something the more the costs come down. That creates an interesting challenge for policy makers. Do we simply wait for these things to happen? Do we believe that by choosing to go further and faster in the direction of renewables we will automatically affect the cost penalty and bring it down?

The key thing is that just as we need many technology levers, we also need many policy levers. One of the policy levers that people talk about – and again it is of immediate interest to economists – is carbon pricing, either through a taxation regime or through a trading regime such as the European Commission’s Carbon Trading Scheme. This involves creating a charge for emitting carbon, and some people think that’s as much as we should do: setting a carbon track and trade system and allowing it to do the work. In some sectors – particularly energy-intensive ones – it will work. If we face a steel mill plant not only with the cost of fuel but also with a charge for emitting carbon, we will intensify yet further the search for energy efficiency. But we can only rely on the market to work in that case because the costs are large and there are professional managers focusing on it. Similarly, we may – albeit debatably – affect transport demand through crisis. And we will certainly affect renewable energy development if we increase the cost of burning fossil fuels – the relative cost of building a wind farm goes down as the relative cost of burning fossil fuels goes up. But without a dramatic increase in the cost

of electricity, it wouldn't make a blind bit of difference to people's decisions about light bulbs or insulation, whether at home or in business. That means that there is a significant role to play in policy and regulation.

I don't think we are going to make the shift from incandescents to fluorescents and then to lighting-emitting diodes (LEDs, which produce the same amount of lumens with 1 watt as an incandescent does with 11 watts) through a carbon price. We can only achieve that sort of switch through regulation, by saying there is a date beyond which it is illegal to sell an incandescent bulb. Similarly, building regulations are key drivers of whether or not people will insulate buildings. Automotive emissions probably have to be driven down by agreements with the car industry on the average fuel economies of the corporate car fleet – which do exist on the European level. Consumer information alone is not enough.

Finally, we may also have to pull a price deal on technology support and subsidy. If the cost of technology comes down as a result of the volume of its production, we may want to intervene in two ways: driving the technology out of the research lab and into development by pump priming the research, or deliberately subsidizing it over the hump to get it up to a scale whereby the cost comes down.

Let me finally talk about what the United Kingdom is doing and whether it's doing enough. The UK has now made a set of target commitments which are in international agreements or in stated government policy, and some are now legally binding within the Climate Change Bill. Under the Kyoto Protocol the country made a legally binding commitment to reduce average annual greenhouse gas emissions (including carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride) by 12.5 per cent relative to 1990 levels during the period 2008-2012. We already have a domestic CO₂ goal of 20 per cent below 1990 levels by 2010, and under the Climate Change Bill, we have also written into law a 60 per cent domestic reduction by 2050. The Bill also requires the government to set five-year carbon budgets. The third carbon budget, for the period 2018-2022, must see carbon emissions in the range of 26 to 32 per cent below 1990 levels.

So in terms of legal commitments we are doing quite well. These are quite stretching commitments and we have a set of policies, taxes and trading schemes in place, including a fuel duty escalator and a



climate change levy, the EU Emission Trading Scheme and renewable obligation certificates. In terms of regulatory and voluntary commitments, we have building regulations and European appliance labelling, automotive voluntary commitments and supplier obligation. In fact, we have a panoply of measures set out in the government climate change programme.

In terms of the Kyoto Protocol we will more than meet the target that we committed to on reducing greenhouse gases. We did a reasonable job of reducing our non-CO₂ greenhouse gas emissions – in particular major reductions in methane from landfill sites – and we reduced our CO₂ emissions in the 1990s as we switched from coal to natural gas. But CO₂ reductions have since flattened out, and we are now way off target for any of our stated targets.

So we need to do more, and there is more in the climate change programme – in the areas of taxes and trading, appliance and building regulation, information and technology support – that the government says will take out 23.4 to 33 million further tonnes of emissions from the present annual level. However, even if it achieves the higher end of that range – 33 rather than 23.4 – we will only just achieve the lower end of the target. So even with the higher end of the policy levers that we are now pulling we can only achieve a 26 per cent reduction, not the 32 per cent reduction considered necessary. We clearly need to do *much* more.

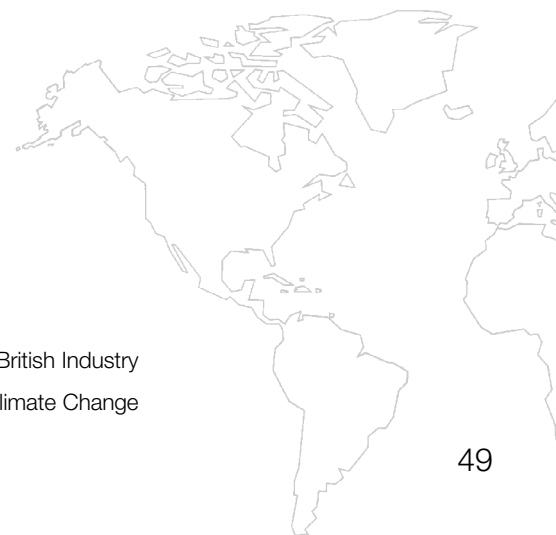
The world is now at the potentially fruitful stage of making a raft of declarative and, in some cases, legal commitments. The European Union has committed to a 20 per cent unilateral cut in greenhouse gases by 2020, rising to 30 per cent if others can agree during negotiations, and has committed to a 20 per cent renewable energy target by 2020, which is actually very stretching. The leading presidential candidates of the United States of America are all committed to some category of cap and trade system. California has made quite strong legal commitments to a 25 per cent cut by 2020, and has an aspiration of 80 per cent by 2050. The French are talking about a 75 per cent cut by 2050. And with regard to the Kyoto Protocol, we now have the Bali agreement to negotiate follow-on commitments. So, we are making progress in terms of commitments, but so far this is not translating into the results that we need.

The abatement scenario that I mentioned earlier had the total level of global emissions beginning a downward trend from 2020 onwards. But the International Energy Agency's latest *World Energy Outlook*

predicts an ongoing rise in emissions beyond 2020, even with all policy levers in place. It concludes that the number and strength of policies under consideration continues to grow faster than the number and strength of policies actually adopted, reflecting a growing concern but more talk than action.

In conclusion, we know that we can cut emissions at an acceptable cost to the economy, but we need to do much more with regard to policy, and we also need to bring in the most rapidly growing developing countries as well. The Chinese are taking steps on energy efficiency, but when you talk to them about emissions cuts they are still unwilling to enter into debate because, as they point out, their per capita emissions are still at half our level. The problem is that even if we manage to cut our own emissions by 2020, China may have overtaken us in per capita emissions, let alone in absolute emissions. There is an immensely important challenge to persuade the leading developing nations, above all China, that they also have a long-term interest.

Lord Adair Turner, former Director-General, Confederation of British Industry
Chair of the Committee on Climate Change



Creating a healthy environment in China

Professor Sian Griffiths

March 2008



As Co-Chair of the SARS (severe acute respiratory syndrome) enquiry for the Hong Kong government, I was made highly aware not only of the global public health challenges we face today, but in particular the public health challenges faced by China – and Hong Kong as part of China. SARS demonstrated that the fight against infectious disease entails not just the clinical aspects of disease control, but also the conditions in which food is produced, the design of our housing and the need for occupational safety.

Following the work with the government, I was invited to the School of Public Health of the Chinese University of Hong Kong where I now work, which has given me new perspectives on the challenges the environment poses for the health of populations in our part of the world.

Necessarily, my account today will be impressionistic. I have to emphasize that I am not an expert on environmental health, and I want to thank my colleagues at The Chinese University of Hong Kong School of Public Health, and Professor Shelly Tse in particular, for their help preparing materials for this lecture.

I will start with some definitions and descriptions, and then go on to consider the physical environment and the health issues relevant to safe water, air, food and occupation, referring to the economic transition which has created a huge migrant work force, and the new challenges for those concerned with creating a healthy population.

Definitions

When we consider health, we do not think just about doctors and illness but about 'wellness'. If we use the World Health Organization (WHO) definition – 'Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' – then the scope for creating a healthy environment is clearly not limited to hospitals and doctors' surgeries, but includes the myriad factors that influence health: agriculture and food, education, housing, employment status and working environment, water and sanitation, and health care services, as well as hereditary factors and lifestyle choices such as smoking.

A historical analysis of public health tells us that we need to be aware of all these factors, and the influence of the environment does not just involve the conditions in which we work and live – whether



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we have water, sanitation, good housing or health-promoting workplaces – but also how we live our day-to-day lives, and how we communicate with and support each other within our societies. High-rise tower blocks in Hong Kong may be less conducive to children going out to play in the park, as mothers will be anxious about letting them go on their own, predisposing them not only to less physical activity and a greater chance of obesity but also to psychological stress.

Thus environmental influences can be social, physical, economic and political. I will focus on the physical but briefly touch on the others, as it is not possible to discuss health in China without doing so.

Mainland China has a population of 1.31 billion people living in 22 provinces, five autonomous regions and four municipalities. Since 1949, there have been tremendous advances in the health of the people. The two indicators used to reflect the health and well-being of a country are life expectancy and infant mortality. In both of these areas China has made terrific strides forward. The average life expectancy of a Chinese citizen, for example, rose from just 35 years in 1949 to 70 in 1997. By 2004 a resident of Shanghai might have expected to live to 80.

This has been brought about by an increase in national wealth (China's current annual rate of GDP growth is around 8-10 per cent), and this has seen areas such as the Pearl River Delta expand at an amazing pace to become a production centre for the world. In the late 1970s Shenzhen, for example, was a sleepy rural area with a population of around 370,000 farmers and fishermen. Today, the population is 12 million and growing, comprising 2 million permanent residents, 6.5 million temporary residents and a large floating migrant population.

While 60 per cent of China's population is in rural areas, rapid urbanization due to industrialization and marketization has led to a huge migrant population. The impact on health has been mixed, with diseases of affluence emerging in the richer eastern cities where obesity is increasing; while in the rural west, poverty-related diseases are still having an impact. Health inequalities continue to exist, with life expectancy a good 10 years longer in the cities than in the most impoverished rural areas, and infant mortality almost 10 times higher in the most impoverished rural areas than in the larger cities. As the economic boom continues, disparities in resource allocation also continue to grow, with a disproportionate effect on the nation's health.

Unrestricted economic and industrial development has caused a deterioration in the environment as the impact and demands of economic growth put stresses on infrastructure and produce harmful side effects. The consequence for well-being is that the health gains of a more affluent society are counterbalanced by the impact of environmental pollution – which is causing increasing morbidity and mortality, and putting stress not only on the inadequate health care system but on people's pockets – to the extent that paying medical bills is the most common cause of people going into poverty. In a 2007 survey medical concern topped the league of social concerns. I want to focus on the impact of the physical environment on health and the challenges this poses by looking at five themes: air, water, food, the working environment and climate change.

How safe is our air?

In 2008 Beijing is to host the Olympics and, as everyone is aware, there is great concern about the health implications for the athletes, such that there is even the potential of rescheduling the games, or at least some events. Air pollution has become a major concern – particularly for its impact on quality of life. There are countless pictures of smog in our cities, not least in Beijing, Shanghai and Hong Kong. We seldom see a clear sky, and of 585 cities surveyed in 2006, only 38 per cent registered air quality that reached national health standards, down from 45 per cent in a 2005 study. Air pollution is a direct result of uncontrolled rapid economic growth. Its sources are combustion of gasoline and other hydrocarbon fuels in growing numbers of cars, trucks and aeroplanes.

And then there are the sources of indoor pollution, for example the burning of fossil fuels, with coal still the major source of energy for much of China. In addition, much domestic cooking makes use of wood alongside fossil fuels, contributing to indoor air pollution. Indoor pollution is exacerbated by the high rates of smoking among men (60 per cent) and recent figures show that smoking continues to rise amongst the younger population. While efforts are being made to stem the tide, there is a long way to go and major considerations such as tobacco production and tax revenue need to be actively addressed. Other sources of air pollution include insecticides and herbicides, radioactive fallout and dust, especially from construction and industrial processes.

While there have been some attempts in Hong Kong to control sources of pollution such as outdoor burning, which has been banned since 1996, comparisons between the pollutant concentrations in cities



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of the Pearl River Delta and other international conurbations show that levels are woefully high. Many expatriates are leaving Hong Kong, citing the poor air quality as their reason – including the conductor of the Hong Kong Philharmonic Orchestra, Edo de Waart, whose son was suffering from asthma. Studies in our schools have shown increased hospitalization associated with air pollution.

How safe is our water?

Water is a prerequisite for life – and clean water a prerequisite for health. China faces a major challenge in providing clean water to its citizens. Many water sources are becoming polluted and industrial wastewater has led to 70 per cent of the water in five major river systems being unsuitable for human use. At present it is estimated that 700-800 million people are drinking contaminated water on a daily basis. Communities along the major river systems are beginning to show the harmful effects and there have been reports of increased rates of cancers, stunted growth, spontaneous abortion and also a negative impact on IQ.

The village of Shangba in Guangdong province is just one example of the problems that can be created by water pollution. Here a government-owned mineral mine and other privately owned smaller mines dumped toxic waste into the local rivers. It is estimated that 250 people died of cancer related to the toxins between 1987 and 2005.

There have been many more stories, including the highly publicized growth of algae turning lakes green with the result that water is unfit for drinking. Other examples of contamination include:

- Cadmium: contamination of the Bei River from mining led to suspension of the water supply downstream.
- Lead: more than 300 children were poisoned following contamination of the village water supply in Hui county, Guansu province.
- Arsenic: 160 people were poisoned following a leak from a smelting plant in Liaoning province.

And contamination also has impacts on the food chain. But of course contamination is not the only problem of the water supply. Having water in the first place is also a very important issue, and the increasing demand for water as living conditions improve and industry booms is confounded by a growing water shortage. The per capita supply is only 25 per cent of the global average, particularly in

the south, and 60 million people find it difficult to get water for their daily needs. Riverbeds dry up, fish die and water quality deteriorates.

How safe is our food?

Food scares are commonplace. In Hong Kong we have had a series of alarms: malachite green in fish farming; contaminated vegetables; oily fish; *Streptococcus suis* in pork; and of course H5N1 avian influenza in our chickens.

The response in Hong Kong has been to create a special government body – the Centre for Food Safety – with regulatory powers. In Shenzhen, food safety and food security have become important issues of concern. With the millions of migrant workers living in dormitories, many in cramped and not too hygienic conditions, the risks of food-borne disease pose a challenge to the local Centre for Disease Control, which has responsibility for control of outbreaks of food poisoning. A recent incident of poisoning resulted in two deaths and a number of hospital admissions – the source being an unlicensed noodle bar.

Issues of food export from China have become highly sensitive – as demonstrated by the recent debate about whether or not New Year dumplings had been sabotaged.

How safe is our workplace?

The pace of change and urban expansion have led to short cuts in many industrial processes. As the WHO report says: ‘The trend towards globalization of trade, while economically beneficial, is introducing a host of occupational hazards to developing countries, where 75 per cent of the global workforce lives and where the technical and social infrastructure is lacking to protect workers from these hazards.’ In the United States of America the mission of the Occupational Health and Safety Act is ‘to assure so far as possible every working man and woman in the nation safe and healthful working conditions’, and is supported by legislation, but in China, the rapid pace and scale of change make this seem a monolithic struggle.

Occupational hazards can be grouped as:

- Physical (noise, vibration, ionizing or non-ionizing radiation, thermal environment, air pressure).

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- Chemical (gases and vapours, organic compounds, metals and dusts).
- Biological.
- Ergonomic.
- Psychosocial.
- Safety.

It should be pointed out that occupational accidents may be **environmental** – due to unsafe conditions – or **personal** – due to unsafe acts.

Inevitably, considerations of occupational safety link back to the nature of the working population and the impact of migration. Employers in, for example, the mining industry, often take short cuts in their rush to deliver the coal needed for the electricity supply for industry. Coal mining accidents are not an infrequent occurrence and account for 80 per cent of all accidental deaths. Other occupational hazards, for the example the high cadmium levels found amongst workers in Huizhou, raise further concerns about the lack of awareness and adherence to occupational health standards, particularly amongst the many small village enterprises.

Not only are there issues around physical safety but social equity is a major concern – along with the responsibility of employers. The migrant workforce is often unskilled, in insecure employment, living in an unstable community and as part of a marginalized group in society. Its members earn less than urban residents, although their income will be higher than what they could have expected in the countryside. While they may be at risk from the environmental factors of their workplace, their health needs can be complex. Not only do they need to understand safe working practices, there are also psychological factors affecting them. In a recent study in Shenzhen the most common complaints for seeking help from a doctor included insomnia and stress-related disorders.

Climate change

It is not only the changing material environment but also its wider impacts that can have health effects. Extremes of temperature are becoming more common, and last winter was no exception. There have been numerous press reports of the big freeze across China. In Hong Kong, this resulted in large numbers of influenza cases admitted to hospital and worries about the impact of hypothermia on the elderly.

This cold winter followed on from a hotter-than-average summer in which parts of China also suffered the impact of heat waves. An added concern is that the impact of heat waves will further contribute to the already widening health and social inequalities since it is the elderly and poorer members of society who are most at risk.

The United Nations Development Programme, in its *Human Development Report 2007/2008*, expresses particular concern for the developing world as the impacts of climate change increase:

The early warning signs are already visible. Today, we are witnessing at first hand what could be the onset of major human development reversal in our lifetime. Across developing countries, millions of the world's poorest people are already being forced to cope with the impacts of climate change. These impacts do not register as apocalyptic events in the full glare of world media attention. They go unnoticed in financial markets and in the measurement of world gross domestic product (GDP). But increased exposure to drought, to more intense storms, to floods and environmental stress is holding back the efforts of the world's poor to build a better life for themselves and their children. Climate change will undermine international efforts to combat poverty...

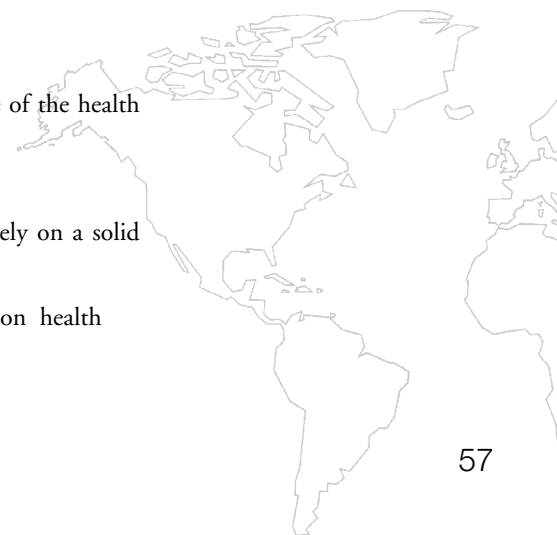
However – we need not sit passively and say it is all inevitable. As the WHO has highlighted: ‘fortunately, much of the health risk is avoidable through existing health programmes and interventions. Concerted action to strengthen key features of health systems and to promote health development choices can enhance public health now as well as reduce vulnerability to future climate change.’

So what are the challenges for the future?

Inevitably in the time available I have been able to do little more than highlight some of the health aspects of the major environmental risks created by the rapid urbanization of China.

There have been huge advances in China, but the sustainability of progress will rely on a solid infrastructure which protects the health of the people. I would suggest four As:

- Awareness – develop and sustain awareness of the environmental impacts on health amongst the public, politicians and key actors.
- Anticipation – targeting on prevention and preparation.



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- Action – at all levels: national, regional, local and individual.
- Advocacy – by those concerned with creating a healthier society.

I would like to finish with a quote from Hu Jintao:

Social development is closely related to the people's well-being. More importance must therefore be attached to social development on the basis of economic growth to ensure and improve people's livelihood, carry out social restructuring, expand public services, improve social management and promote social equity and justice. We must do our best to ensure that all our people enjoy their rights to education, employment, medical and old-age care, and housing, so as to build a harmonious society.

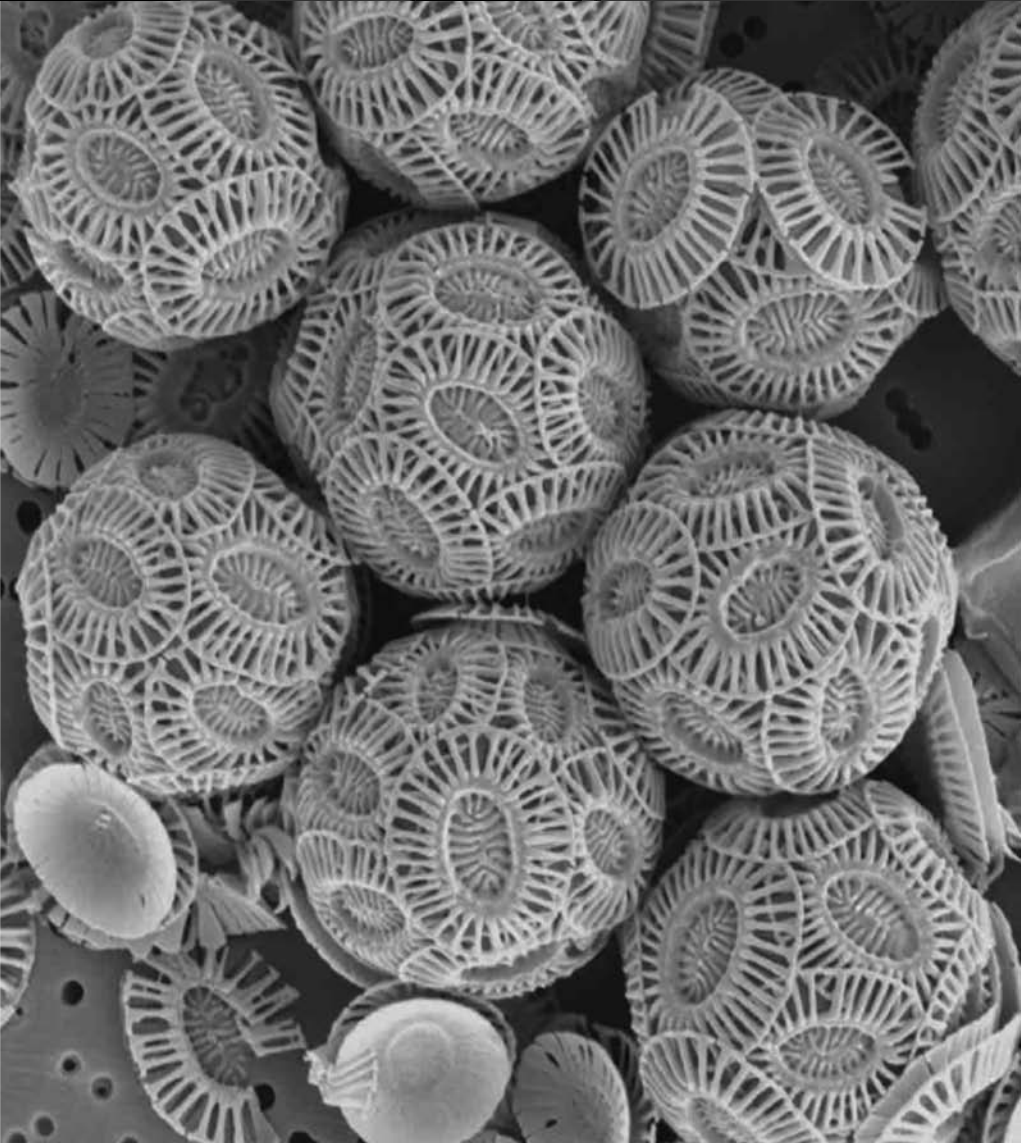




Ocean acidification: the other CO₂ problem

Professor Nick Owens

April 2008



Everybody has heard of the ice core records – going back 800,000 years – showing repeat patterns of rising atmospheric carbon dioxide concentrations and rising global temperatures. Climate change is a hot topic. But the other CO₂ problem – the acidification of the oceans – still goes largely unrecognized. Neither the scientific literature nor the more popular variety has offered much coverage of the issue. A quick trawl through Times online throws up more than 5,000 hits for the words ‘climate change’, but only a dozen for ‘ocean acidification’ (April 2008). This is a totally unscientific indicator, of course, but it is nonetheless a reasonable measure of what is going on in terms of our understanding, and indeed basic awareness, of this other big CO₂ problem.

Through the natural carbon cycle – which everybody learns about at school – there are continual fluxes of carbon between the atmosphere and the oceans, and Henry’s Law on the partial pressure of gases ensures that the relative amounts are maintained in equilibrium. Since the dawn of the Industrial Revolution, however, we have massively increased the amount of CO₂ in the atmosphere through our use of fossil fuels, the formation of cement from limestone, and so on. So ocean uptake of CO₂ has increased, with a net inward direction of carbon from the atmosphere into the oceans of approximately 2 billion tonnes of carbon per year. This is roughly a third of all the CO₂ produced by human activities. So ocean uptake has actually slowed the build-up of carbon in the atmosphere, a process which to some extent is reducing the rapidity of climate change.

But what does it mean for the marine environment?

On entering the ocean, CO₂ combines with seawater to produce carbonic acid (H₂CO₃). This rapidly dissociates into carbonate ions (CO₃²⁻), bicarbonate ions (HCO₃⁻) and hydrogen ions (H⁺). That is the very simple first step and it is unequivocal. We know that it happens. And it is the concentration of hydrogen ions that determines acidity or alkalinity – the more hydrogen ions, the further down you go on the pH scale from alkaline to acidic. What comes next is a rapid reaction between the hydrogen ions and carbonate ions present in the seawater. Now the ocean has very large quantities of carbonate ions from various sources, and the hydrogen ions react with these to produce another bicarbonate ion; they are effectively mopping up the carbonates. The relative balance of these forms of inorganic carbon in seawater changes, leaving you with very small quantities of dissolved carbon dioxide, rather more carbonate, and a very great preponderance of bicarbonate.

One of the things that is of really great importance to marine organisms – for growing and maintaining their skeletons or hard structures – is the presence of calcium carbonate (CaCO_3), which includes familiar minerals like calcite and aragonite. Carbonate minerals form through the reaction of calcium ions (Ca^{2+}) with carbonate ions (CO_3^{2-}). Conversely, when the carbonate ions are removed – as happens when they are ‘mopped up’ by the hydrogen ions – the calcium carbonate essentially dissolves into its constituent forms.

One important feature of this mineral formation or dissolution process is that the global distribution of carbonate in the oceans is affected by temperature and pressure. More minerals are present where the water is warm and shallow, while there is a tendency towards the dissolution of the carbonate in deeper cooler water where pressure is higher. So surface waters and lower latitudes are higher in carbonate minerals, and deeper or higher-latitude waters have an undersaturation of the mineral. It is that natural distribution of carbonates that is being seriously disturbed by the increased ocean uptake of CO_2 .

On average the pH of the world’s ocean is around 8.1. It varies from place to place, partly due to the amount of plant life, partly due to temperature and pressure. Now if we assume that we will continue to burn fossil fuels until they have effectively run out, we will get an ongoing accretion of atmospheric carbon up to 2250 or thereabouts, and this will then decay only very very slowly. The ocean will continue to absorb CO_2 long after we stop producing it, slowly pushing seawater down the pH scale and reducing alkalinity by as much 0.7 pH units. Now, 0.7 may not sound like very much, but when you consider that pH is a logarithmic scale, it is a very significant number. In fact we have already shifted the pH of the ocean, reducing it by 0.1 of a pH unit since preindustrial times in the surface waters, and we are beginning to see penetration down into deeper water as well. Now 0.1 of a pH unit may seem a very trivial amount, but it represents a 30 per cent increase in the quantity of hydrogen ions in the ocean – already. Should we continue to burn fossil fuels at the present rate we will see levels of hydrogen ions right down through the ocean water column that have not been seen for at least 55 million years and possibly longer. This is a very significant and major perturbation to the Earth’s system.

Unlike climate change predictions, of which there are many and they are uncertain, the chemistry and physics involved in ocean acidification is very simple and very certain. One of the uncertainties about climate, for example, is how clouds operate, or perhaps the way that ice shifts and moves. These are



complicated dynamic systems that are very difficult to predict. But what we are talking about here is straightforward unequivocal ocean chemistry and the simple physics of pumping CO₂ into the ocean. Of course we cannot be certain how high the concentrations of atmospheric carbon will go before they begin to flatten out. We might even manage to keep them at 500 parts per million, but even that, in 100 years or so, will inevitably take us to an ocean pH that the world has not seen for 25 million years. Some people have suggested that we are heading for an ocean pH that hasn't been seen for 300 million years.

Back to the minerals now, because this is where we are starting to have the interaction with the biology. Measurements and predictions of aragonite saturation levels show an alarming picture: during the pre-industrial period, the majority of the ocean's surface waters, stretching from (very roughly) around 40° North to 40° South, were classed as adequate to optimal for the existence of calcifiers. In the 1990s, this band stretched, perhaps, from only 30° North to 30° South, though it was still a substantial part of the ocean. By mid-century, however, only small pockets of adequate saturation are expected to remain, with the vast majority of the ocean ranging from 'marginal' to 'low', and by the dawn of the next century, there will remain only small areas of marginal saturation, with most of it 'extremely low'.

So what does all this mean for the ocean and the organisms that live in it? There is a whole range of organisms that use calcium carbonate minerals to make their hard structures, the most obvious among them being the reef-building corals. It is no coincidence that corals are particularly abundant in warm, shallow waters where the mineral aragonite is very abundant. They cover around 1.28 million square kilometres, which is less than 1.2 per cent of the world continental shelf area, but are highly biologically diverse, harbouring some 25 per cent of known marine species. Corals are fairly easy to experiment on, and we know that they cannot secrete stable forms of calcium carbonate (especially aragonite) at a low pH. So we are getting a very marked reduction in the rate of coral skeleton formation – of around 20 per cent, rising to 40 per cent over the coming decades, as a result of what we have experienced already in terms of reduction of pH. At one level, of course, no one would wish to see the reduction of corals just for their own sake. But they are also enormously important around the world. Recent data from the World Bank estimate that over half a billion people fundamentally rely on healthy corals for food and other goods and services, with an estimated value of \$375 billion. Corals also provide natural sea defences for low-lying islands, usually rather poor islands at that, so there are massive socio-economic consequences associated with coral destruction.

There are also some very extensive cold corals that tend to be in deep water. They have only been discovered relatively recently and they have been very little studied compared with their warm water cousins. But they are clearly very abundant, with new colonies being discovered all the time. They are found everywhere in deep cold water and are particularly important off the coast of the United Kingdom. They can form very large structures of as much as 20 metres in depth and 100 metres across, and some are perhaps 8,000 years old, and are havens for biodiversity, harbouring extensive fish stocks which use them as feeding grounds and for shelter. Now bearing in mind that these deeper cold-water environments are already low in minerals, then the introduction of CO₂ and the lowering of pH will reduce those levels even further, thus putting deep-water corals under extreme pressure. The depth below which mineral desaturation occurs – where there are insufficient minerals for marine calcifiers to thrive – is known as the ‘saturation horizon’, and shallowing of the aragonite saturation horizon will be greatest in the higher latitudes, making these ecosystems very vulnerable.

Molluscs, of course, require calcium carbonate in mineral form to make their shells, and a whole range of responses to changing pH has been observed in experiments with these organisms done at Plymouth. A lowering of the pH to 7.3 results in a 50 per cent reduction in growth, and at a pH of only 7.0 (ie neutral), scallop mortality was found to be at 100 per cent. Juveniles and spat (larvae) tend to be particularly sensitive. So there are some very real concerns about the natural communities of molluscs, but also again about the economic consequences for commercial shell fisheries. Echinoderms such as sea urchins, sea stars and sea slugs are particularly sensitive to lowering pH because they have no impermeable barrier between the ambient seawater and their internal body cavity, so have little ability to control the acid-base chemistry within their bodies. The heart urchin (*Echinocardium cordatum*), when exposed to reductions in pH, showed considerable deterioration of the digestive tract, affecting nutrient uptake, growth and, ultimately, reproduction. Again, echinoderms are very important for the ecosystem, providing services in terms of turning over material in sediments and so on, and as food for fish species. Many of them are commercially important too, both in themselves and in supporting active fisheries.

There are also some quite quirky things happening here. Take the edible periwinkle (*Littorina littorea*), and its survival mechanisms when threatened by the green shore crab (*Carcinus maenas*). We have known for some time that there is considerable communication between these two organisms in the form of chemical cues being picked up by the periwinkles. When they detect the presence of crabs,



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they lay down much thicker shells. In a future ocean where the availability of carbonate ions is reduced, snails may be less able to thicken their shells and could therefore be more vulnerable to predation.

There are likely to be all sorts of unexpected consequences for the ecology of these sorts of organisms, particularly in the smaller plankton species, and there is currently very little idea of the subtleties that may occur. But what experiments have been done show that these organisms are very sensitive. There is evidence to indicate that one might expect reduced reproductive rates in undersaturated waters, and that marine zooplankton passing through plumes of CO₂-enriched seawater suffer high mortalities.

There is also some debate on the relative importance of some of these organisms. Take, for example, *Limacina helicina*, a shelled pteropod found in polar and subpolar waters of both the northern and southern hemispheres. They are basically little winged snails that float and flap around in the plankton, and are believed by some to be a very important component of the food chain. There have been instances where these things have shown up in vast quantities in sediment traps, and there are areas of the world ocean where the sediment is made up primarily of the remains of these organisms, so it is almost certain that they have an important role to play. And it is also certain that they need high levels of aragonite saturation to make their shells. But current scenarios for ocean acidification indicate that by 2050 there will be few areas where these pteropods can survive, and by the end of this century almost all the ocean – and particularly polar waters – will be so undersaturated that the pteropod shells will simply dissolve.

So what will these pteropods do? There is a possibility that they will just move: they are planktonic after all. But there are quite potent and marked frontal boundaries which isolate the Southern Ocean, so planktonic movement seems unlikely. There are some indications that, given time, some organisms could adapt through genetic selection and adjust to the lowering pH. The concern, however, is the speed at which acidification is happening, almost certainly precluding sufficiently rapid evolutionary change.

One kind of organism that has been under study is coccolithophores. These are in fact a plant – they photosynthesize – and are quite beautiful under the microscope, like little footballs with round plates like dinner plates – actually shells made of calcium carbonate. And so of course they need these minerals

in saturating quantities. Not only are they beautiful; they are important components of the ecosystem and are believed to have been so over geological time scales. Their story is quite fascinating. They are miniscule – about 2 microns (millionths of a metre) in diameter – but occur in such vast quantities that you can actually see coccolithophore blooms from space, appearing as milky white swathes hugging the land masses, particularly around Europe and northeast America, the South Pacific and the Southern Ocean. Their numbers are absolutely unimaginable. So you have got this tiny little thing in such quantities that it can be seen from space. And they have been produced in these enormous quantities over such long geological time periods that where they sediment out, all their chalky plates have combined to form features such as the White Cliffs of Dover. This is quite a challenge to one's thinking about scale – to have something 2 microns in diameter that can be seen from hundreds of kilometres off in space and that has produced solid rock many metres thick.

Another interesting feature is that as the coccolithophores die they release a volatile sulphur compound which eventually gets out into the atmosphere as dimethyl sulphide (DMS). Now one of the interesting things about DMS is that once in the atmosphere it oxidizes to sulphur dioxide (SO_2) aerosol particles, around which clouds form. So it is possible that coccolithophores are a natural temperature regulator that may have played an important role in this way over geological time scales. Their very presence in the ocean also results in a lowering of the sea temperature, as their high reflectivity reflects sunlight back out to space (which, of course, is what makes them visible from so far away). If you measure seawater temperatures within these blooms of coccolithophores you find the water temperature is cooler than outside them, so you have a double cooling effect from these creatures.

There has been some pretty good evidence of what happens when you expose carbonate-dependent organisms to a lowering of seawater pH associated with the sorts of atmospheric CO_2 concentrations that we are almost certainly committed to. And it seems pretty convincing. Or at least it did – until the appearance of an article in *Science* in April 2008 that has rather turned this simple notion on its head. It has not totally discredited theories about the negative impacts on marine life of ocean acidification, but it does mean that things are more complicated than we thought. The paper in *Science*, by Iglesias-Rodriguez and others, explored the findings of an investigation into the effects of CO_2 on the coccolithophore species *Emiliania huxleyi* in its formation of calcite plates. Contrary to expectations, they found that raising CO_2 and lowering pH actually led to the plates getting bigger and thicker.



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Production of the mineral was in fact stimulated by an increase in CO_2 . So it is thought that certain types of coccolithophores might actually do quite well in a high- CO_2 environment. This is clearly more complicated than we at first thought and, like all good papers, the final paragraph said 'we need more research'. It is an interesting tale that is developing all the time.

One of the features of changing pH relates to the availability of key nutrients for phytoplankton and bacterial growth. There are many ionic compounds in seawater that have different forms depending upon the pH. Different forms of nitrogen, in particular the ions ammonia and ammonium, for example, change their quantities and proportions depending on pH. Different inorganic phosphate ions also shift their balance as pH falls. Changes in the relative proportions of these nutrients may well have an effect on plankton diversity. Colleagues in Plymouth have modelled what might happen in the North Sea if we assume 'business as usual' in the burning of fossil fuels, with atmospheric CO_2 concentrations moving from the current level of around 380 parts per million (ppm) to 700ppm or beyond. Their work suggests that by 2050 some areas of the North Sea will have a different pH range from today's, and by 2100 most of the region will have undergone a drop on the pH scale of 0.3 units or more. This will lead to a change in the ratio of nitrate to total nitrogen (raising the nitrate), with potential effects on denitrification and eutrophication, and as yet under-researched physiological impacts on fauna.

Looking at the fossil record going back 600 million years, the planet has experienced very high CO_2 concentrations during interglacial periods, while through times of glaciation the CO_2 has been low, if with some temporary hotspots. During the Paleocene-Eocene thermal maximum, there was a big spike of CO_2 into the atmosphere, a corresponding increase in global temperature, and almost certainly a very rapid acidification event in the ocean, much as we are experiencing today. The CO_2 probably spiked as a result of a release of methane from the thermofrost, rapidly oxidizing into CO_2 . And much of that carbon was absorbed into the ocean.

Of course there is a massive amount of carbon stored in the ocean, far more than in the atmosphere or biosphere, and over long time scales this has formed carbonate sediments that have acted as a buffer to fluctuating seawater acidity. But where you have a very rapid increase in CO_2 uptake, the ocean cannot absorb it and so you get a big slide down the pH scale. The amount of CO_2 entering the ocean in the Paleocene-Eocene thermal maximum was so rapid that the ocean was incapable of buffering it.

Sediment cores taken from the Weddell Sea from that period show a marked change in the colour of the sediment resulting from a fundamental and profound shift in the composition of the organisms in the oceans. It is estimated that something over 50 per cent of the calcifying organisms in the ocean at the time became extinct. This is very graphic evidence of what happens when you have a rapid shift in the acidity of the ocean, and it is rather chilling to think that as far as we are aware, the rate of change in the acidity of the ocean today as a result of human activity is faster than occurred during the Paleocene-Eocene thermal maximum. There is no doubt whatsoever that there was a major extinction in the oceans at that time and this is part of the concern today.

I thought I would finish by asking whether the ocean could come to our aid. As we know the ocean is soaking up CO₂ through natural processes. Roughly half of the carbon that has been mobilized by humans since the industrial revolution has ended up in the ocean. Could the ocean be manipulated further to help solve the problems we have caused – not only the acidity problem but also the climate change problem?

There are very large areas of the world ocean which, on the face of it, should have greater quantities of plant life than they currently do, with plenty of nitrogen and phosphorous and so on. These are called high-nitrogen low-chlorophyll areas, and they occur in different parts of the world. The Southern Ocean certainly has a big one, the equatorial Pacific another. It has been suggested that if you fertilize these areas of the ocean with iron you can stimulate the plant life and thereby get a greater CO₂ uptake from the atmosphere. Experiments with iron fertilization in the Southern Ocean have indeed achieved phytoplankton blooms large enough to be observed from space. So people have begun to think very seriously about fertilizing the ocean. But there are many problems with potentially serious consequences. First, to have any real impact on atmospheric CO₂ concentrations, you would have to do it on a vast scale – the size of the entire ocean, not just a patch of it. The time scales involved are vast, bearing in mind that the carbon we are burning in the form of fossil fuels was laid down in part by these kinds of plankton blooms over millions of years, not just a few hundreds. They happened over geological time, and it would be impossible to stimulate the system to soak up that quantity of carbon over the sort of time scales that we require. We also know that plankton blooms give off compounds like methane and nitrous oxide, both highly potent greenhouse molecules in their own right. Thus we would be up against a major perturbation of the natural system with some very serious consequences.



Unfortunately, there are several companies who are lured by the carbon trading notion and are planning on doing this sort of thing right now. Personally, I think this is utterly insane – and you don't often get scientists being as bold as that.

Closer to the realms of the possible, perhaps, is scrubbing out the CO₂, pressurizing it and turning it into liquid, and piping it to the deeper parts of the ocean. The Monterey Bay Aquarium has done some experiments with putting liquefied CO₂ into the ocean, where it basically just rolls around on the seabed. Now this is a good way of 'burying' carbon dioxide, but only temporarily. It will eventually dissolve into the seawater, making it more acid. A more realistic possibility is the near-permanent burial of CO₂ in the rock formations from which oil and gas have been extracted. This is so-called geological sequestration. CO₂ is captured at source, compressed and injected back down into the rock strata. There are some experimental sites where this is already going on, including at an oil field in Norway. The United Kingdom, too, is considering this as a serious option. An assessment of the types of rock formation suited to this type of carbon storage concludes that there are plenty of appropriate sites around the world, including opportunities in the North Sea.

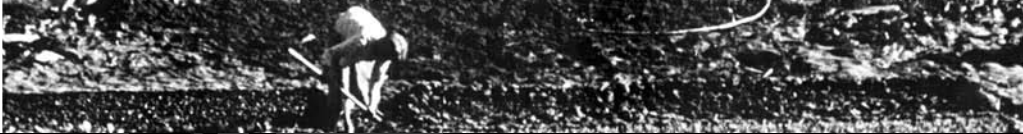
There are, however, many issues yet to be addressed, not least leakage and whether this might give rise to a serious acid event in the locality of the carbon storage site. Modelling work that has been done on this suggests considerably different responses at different times of the year. If you get a release in the early part of the year before the ocean has had a chance to stratify, you might get slight acidification but it would be short-lived and much of the carbon would go straight out into the atmosphere. If, however, you get a leak later on in the year when the ocean is firmly stratified, you would get quite significant acidification in that region of the ocean. So there are some serious decisions to be made if we go down this route.

As mentioned earlier, not much has been written on ocean acidification relative to the mass of literature on climate change. But there are a couple of good sources of information: the Royal Society produced a report on the topic a couple of years ago (*Ocean acidification due to increasing atmospheric carbon dioxide*, available on the web, <http://royalsociety.org>) with very easily accessible information and some good references to primary sources. There are also some interesting websites, including the Ocean Acidification Network, a very serious and highly erudite site run by the UNESCO Intergovernmental Oceanographic Commission and the Scientific Committee on Oceanic Research.

I am sure we all have our own personal views on whether concerns about ocean acidification are simply another distraction. But there is no doubt that by burning fossil fuels we have reduced the ocean's surface alkalinity, and the longer we go on pumping CO₂ into the atmosphere, the longer this process will continue and the deeper it will go. The chemistry behind it is unequivocal, even if the biological responses are complex and largely unknown. Alongside climate change, this is a very strong argument indeed for curbing our emissions, not just mopping up after ourselves.

Professor Nick Owens
Director, British Antarctic Survey





International environmental governance

Professor Robert T. Watson

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There are international conventions for stratospheric ozone depletion, climate change, biodiversity and desertification. There are no conventions for air quality, water or forestry, though we do have a good deal of regional or national legislation on each of these. The problem is that with a number of different conventions and legislative structures covering the various environmental themes, we tend to think through the policies for one while neglecting the implications for another, so there is some degree of dysfunctionality in the way we approach the policy process at both national and international levels. Whether in the United Kingdom, within Europe or in developing countries, one department looks at climate change, another at biodiversity, a different one at forestry, and yet another at water.

We have to recognize that we have multiple environmental issues to deal with, of which climate change is but one, though it is the one that the world is focused on at present. As climate begins to change, it will have an effect on the radiation budget of the atmosphere and the stratosphere, which in turn has an affect on stratospheric ozone, and stratospheric ozone in turn has an affect on the Earth's climate, particularly in the polar regions. Equally, a changing climate has an effect on biodiversity and ecosystems, and as we change our ecosystems we modify the exchange of energy and chemicals between the atmosphere, the ocean and the land, so that it feeds back again on the climate system. There is no question that climate change has a significant effect on forests and in turn these affect the climate. Climate change clearly affects water, land albedo and desertification, and it has an impact on air quality. In other words, we cannot look at climate change in isolation from these other environmental issues, which are also issues of development and national security.

The tendency to isolation is also one of the fundamental problems of assessment. Until recently, even the scientists tended to look at each of these issues separately rather than at the links between them. But if we do not look at them in a much more holistic way we will probably not have the informed policies that we need. We can miss out the synergies and, even worse, there could be trade-offs that we don't understand – policies that will be good for climate change may well be bad for biodiversity, for example.

Not all the areas of environmental concern actually have an international assessment process. To look at three: stratospheric ozone, climate change and biodiversity all have conventions and protocols. There is an assessment process embedded within stratospheric ozone, and we have one that is linked to



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but not embedded in the climate change process (the Intergovernmental Panel on Climate Change – IPCC), but there is no assessment process linked with biodiversity. Instead it has a number of rather poor ad hoc processes.

Science in policy making

While science can only ever be one of the many necessary inputs to decision making, comprehensive scientific programmes at the national and international level are absolutely essential to inform public policy. We have some pretty strong programmes in general for the natural sciences: climate change, biodiversity, or stratospheric ozone depletion. But we have underinvested in the social sciences – the behavioural issues linked to the environment. Too many people think we can solve the climate issue through technology combined with policy. But if we don't understand people, individual and community behaviour, the private sector and governments – and how they make their decisions – we will miss out. Technology is crucial, but so are the behavioural issues.

We have good international coordination of some of the international programmes that relate to biodiversity, climate change and ecosystems, such as the World Climate Research Programme, the International Geosphere-Biosphere Programme and the international human DIVERSITAS programme addressing biodiversity, though the latter – which is indeed a social science programme – is pretty weak.

A further weakness is that we have inadequate private- and public-sector funding. Provided that there is open, transparent, independent peer review of the research – whether funded in a collaborative way between the public and private sectors or just by the private sector – we really should be promoting far more public-private partnerships. And then it is absolutely crucial to bring everything together – the scientific, the technical and the economic – through the best experts from all stakeholder groups: universities, government laboratories, the private sector and the NGOs. Indigenous and local knowledge also needs to be integrated with modern scientific knowledge, though here the difficulty is that little of it is written down, and what is written down is not peer reviewed.

One of the big challenges is how to bring together the various types of research. Of course effective communication is absolutely crucial, though this is something that we tend to be rather bad at. Most scientists talk in jargon, so for politicians and the media in general we are pretty incomprehensible.

What is an assessment?

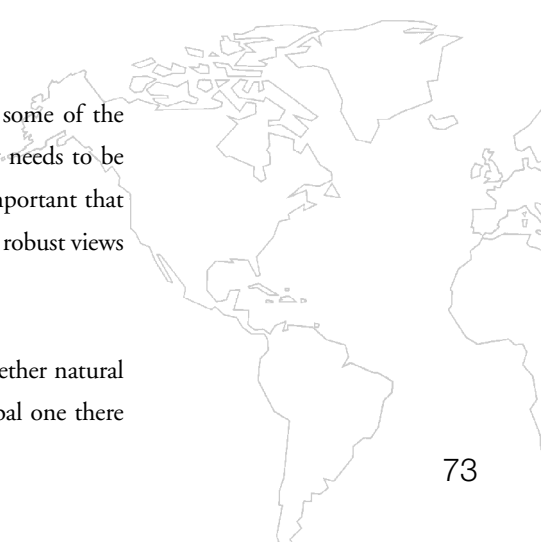
An assessment is more than a review. It is a critical evaluation, an expert judgement of what constitutes robust knowledge and of what is uncertain. Its aim is to reduce complexity, especially for ministers, and to add value. And if it is to have an impact it must be demand-driven, not supply-driven. The users of the assessment have an important role in defining its scope, alongside, of course, the academic community.

So what are some of the critical features of an assessment? Assessments must be open, transparent and representative, and they have to be legitimate with respect to all the stakeholders you are trying to influence. The process is as important as the results: if you get it wrong, you won't have stakeholder confidence and the results won't be used. Success requires a very bureaucratic approach, with well-defined principles and procedures about how the peer review will be done and by whom, and how the resulting documents will be accepted and approved. The review is an essential part of the process – without it, research and assessments are worthless – and it is not unusual to have an assessment reviewed twice. This is a huge amount of work involving governments, the academic community and the public sector.

Whether you want to influence governments, the private sector or civil society, they must be involved in helping to define what they want to assess. With regard to maximizing the potential for influence, I would argue (even though many academics would disagree) that assessments should be policy relevant but not policy prescriptive. They should not be normative and should not make recommendations. The private sector and governments tend not to listen if you tell them what to do, so options for action are far more powerful than recommendations. The 'if... then...' approach generally has the greatest success, and of course it must be evidence based.

It is interesting trying to differentiate the evidence from the ideological positions of some of the authors involved in assessments. Different authors present different views, and every view needs to be taken into account, even if it is supported by only 10 per cent of the literature. So it is important that policy makers understand what is robust and what is not, while bearing in mind that the less robust views have to be understood and taken into account.

The best experts in the world need to be balanced across the disciplines – bringing together natural sciences with social sciences and technologies, and if the issue is an international or a global one there



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must be expertise from both developed and developing countries. It is absolutely crucial that the experts are there in their individual capacity, not representing their government, the private sector or an NGO.

Assessments should be holistic in scope. They should cover risk assessment and clearly define and separate it from risk management: the key issue is to communicate the risk in terms of probabilities. We are fairly good at identifying where the uncertainties lie – an essential element of any assessment – but the implications for policy formulation (or risk management) are much trickier to pin down. I have already said we need to use both traditional and institutional knowledge, which must come into play on the local and global scale as appropriate. For many climate change issues, for example, you can take a global perspective to bring together information leading to a mitigation strategy. But when it comes to water resource management or biological diversity, then it has to be a very local perspective – at least at a watershed or regional level – and communications with local stakeholders are absolutely crucial.

Key characteristics

An assessment must be multi-thematic, bringing together the environment, technological, social and economic perspectives. It must be multi-spacial, using a consistent framework from the local to the global. It must be multi-temporal, examining what we can learn from the past and identifying a likely or plausible future. There should be multiple sponsors and maximized stakeholder involvement. Indigenous and institutional knowledge need to be integrated, and scientific knowledge, technologies, institutions and policies must all come under scrutiny.

What sort of assessments have we done? The International Ozone Assessments began in 1981 and have continued until the present. They have been intergovernmental, with governments approving their broad scope, and have undergone expert peer review (with no governmental involvement). These have been unbelievably influential on both national and international policy formulation, and also with respect to the private sector. Understanding the links between what we were doing, putting chlorine and bromine into the atmosphere, and the ultimate effect of an increase in skin cancer, captured the attention of the public and the policy makers alike. I shall return to the ozone assessments later.

The IPCC started in 1988 and is on-going. The chairmanship of Burt Bolin really set up the IPCC in the right way. It started off very simply: our first working group on the science of climate change involved

only about 40 people, whereas more recent working groups probably brought about 300 people to the table. But it has always been intergovernmental, with governments approving the scope of each of the working groups. There are three working groups – one on the science of the climate system, one on impacts and adaptation, and one on economics and technological issues. There is also a synthesis report that integrates the knowledge of the three. This worked very well in the *Third Assessment Report* (I am biased about this one because I chaired it). Unfortunately the *Fourth Assessment Report* involved far less integration of the three groups, not because of the scientists but because the governments – largely led by the United States of America and China – did not want a full synthesis.

The IPCC has had excellent expert government and peer review of the summaries for policy makers, a process that typically takes four, five or six days, and results in an approved 20-page summary (boiled down from around a thousand pages). Many in the academic community think it inappropriate to involve governments in approval of a document written by experts, but I would argue vehemently that this is part of the process. Only when governments read and approve these documents on a word-by-word basis will they begin to inform policy. Simultaneously, of course, the scientists maintain ownership because, while the document may undergo changes, the academics are there to ensure that there is no distortion. The IPCC has undoubtedly been influential on the policy process, albeit limited in the United States, though here, too, it is starting to penetrate. Some of the big multinationals are using it, as are some individual states such as California and New York. The religious right, amazingly, is also starting to use it, arguing that climate change is a serious moral and ethical issue.

The Global Biodiversity Assessment was a brilliant non-governmental expert review document, but it was totally supply driven. Realizing that the Convention on Biological Diversity (CBD) had no international assessment process, a bunch of us simply got together and did one – a thousand pages with over a thousand contributing scientists. It was a superb academic document, but because the governments did not ask for it and it had no appropriate mandate in the convention, it had almost no impact on policy. It was a valuable lesson: do not do supply-driven assessments; make sure that there is a need and that the user community has asked for one.

So when we did the Millennium Ecosystem Assessment a few years later, it was non-governmental but tied to the intergovernmental process (e.g. CBD; United Nations Convention to Combat Desertification



– UNCCD; Ramsar Convention on Wetlands). It underwent both expert and informal governmental review, and there was a broad range of stakeholders on the board of directors, including users and scientists. It was also multi-scale, from local to global. But there were relatively few governments involved, which was its biggest weakness, and it has taken a number of years to catch on. It is, however, beginning to have an impact. The UK government, for instance, has started to put together a policy arguing that the country should take an ecosystem approach both in the management of natural ecosystems and with regard to the implications of infrastructure such as roads. Its main weakness is that it was non-governmental.

Our latest major assessment is the International Assessment of Agricultural Science and Technology for Development. This was intergovernmental but with a multi-stakeholder bureau. The bureau was made up of 60 people, 30 governments, 30 members of civil society, six from the private sector, six NGOs, six producer groups, four consumer groups, and eight international organizations dealing with agriculture. It was sponsored by seven international agencies (World Bank, Food and Agriculture Organization, United Nations Environment Programme, United Nations Educational, Scientific and Cultural Organization, United Nations Development Programme, World Health Organization and Global Environment Facility) and had reasonably significant amounts of money from governments and a little from the private sector. It underwent three expert and government reviews. The plenary approved the scope as well as the summaries for decision makers and the synthesis report. It was multi-thematic, multi-temporal and multi-scale, including a global and five sub-global assessments.

Did it work? It was an incredible social experiment, with a bureau that effectively went all the way from the private sector through to the NGOs and covered some contentious issues – transgenics and trade, for example. These are far more contentious than anything we had touched upon in the IPCC or Millennium Ecosystem Assessments. There were people in the room that would not usually even begin to talk to each other: Pesticide Action Network, Greenpeace, Monsanto... So it was an incredible experience and I shall detail some of the results later on.

Assessment governance structures

So what are the pros and cons of different governance structures? The pro for the non-governmental one is that it is typically driven by scientists, but this carries the downside of little buy-in by the other stakeholders. The Global Biodiversity Assessment is a perfect example of that. The Millennium

Ecosystem Assessment made greater effort to involve all users, but it still lacked true government buy-in. The intergovernmental approach, such as the IPCC, gets good buy-in from governments – even though some still walk away, as the United States did from this one – but can have a more limited impact with other stakeholders. The hybrid – the agricultural assessment – has everybody on board but is a real challenge given the range of views. Nonetheless I would always argue for the hybrid. The transaction costs are huge but at least it brings everybody to the table, even if they then walk away: the private sector turned its back on the agricultural assessment three months before its finish because we were not saying very positive things about pesticides or transgenics.

In the last two years there have been seven major international assessments: the *Millennium Ecosystem Assessment*; the *2006 Scientific Assessment of Ozone Depletion*; the Consultative Group on International Agricultural Research (CGIAR) *Comprehensive Assessment of Water Management*; the *IPCC Fourth Assessment Report*, the fourth *Global Environment Outlook*; the *Assessment of Agricultural Science and Technology*; and the upcoming Organisation for Economic Co-operation and Development's *Environmental Outlook 2008*.

In the next six months some 40 people will be coming together to do a synthesis of all these global assessments. I think they are basically saying the same thing, and that what is now needed is to focus on policy implications that cut across all the different conventions and international organizations. So our synthesis is to spend only five or 10 pages on the scientific interlinkages, and 20 to 30 on the policy implications, what types of policies will have positive synergies across the various issues, and where there are significant trade-offs.

Assessment findings

Of course the most successful assessments are driven by scientific research, and an assessment is only as good as the knowledge base in the literature. Assessments do not try to add new knowledge. Rather they synthesize existing knowledge.

Stratospheric ozone

In the 1970s we had a theory that chlorine and bromine destroyed stratospheric ozone, but there were no observations to prove it, let alone link cause and effect. We effectively began to do ozone assessments in



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1981, but it was a few years before data on the Antarctic ozone hole, gathered at the Halley Bay research station by Joe Farman and the British Antarctic Survey, revealed the extent of the problem. In 1987 we got the Montreal Protocol, which put a freeze on the growth trend of the long-lived CFCs (11, 12, 113, 114 and 115) and imposed a 50 per cent cut on the industrialized countries but no obligations on developing countries. Our 1989 assessment explained how human activities – putting chlorine and bromine in the stratosphere – were destroying stratospheric ozone, leading to the London Amendments (1990) for the gradual phase-out of CFCs. Then we realized that we could actually see downward seasonal ozone trends. The mistake we had been making was to take all the ground-based observational data from the Dobson stations and look for an annual global average, so we had failed to notice that ozone thinning was a function of latitude and season – exactly what the theory said it should be. An assessment of these findings quickly led to the Copenhagen Amendment (1992) for faster phase-out. We then actually started to see increases in ultraviolet radiation at ground level, findings that came out in our 1994 assessment, and led to the Vienna Adjustment which put caps on other ozone-depleting substances. We also at that time started to see that ozone losses are as significant in the Arctic as in the Antarctic. By the time of our 1998 assessment, we were able to report a detectable reduction of ozone-depleting chemicals in the lower atmosphere. This one led to the Beijing Amendment, with new controls and trade limits. By 2002 we were able to assess the time period involved in ozone recovery.

This was fundamentally excellent research brought together in a series of international assessments, each one leading to new regulations, such that all long-lived CFCs and bromofluorocarbons have been banned, as have most short-lived compounds. There can be a superb linkage between good academic science, international assessment, international agreement and effective policy for change. Obviously we can never be absolutely sure what would have been the effect of stratospheric chlorine without the Vienna Convention, the Montreal Protocol and its amendments, but it would have been going off the scale during the next couple of decades. Each amendment has done a little more to bring down the levels of these compounds in the atmosphere, and the most recent – the Beijing Amendment – aims for total recovery of the ozone layer. All the ozone-destroying compounds have either peaked or are close enough to peaking for the ozone layer largely to have recovered in around 50 years time.

This process raises an interesting question about how much evidence you need before you take action. It was in 1974 that Sherwood Rowland and Mario Molina postulated that chlorine and bromine would

destroy stratospheric ozone. It took 10 years to get a convention and two more to get a protocol, with effective amendments following on. But with long-lived substances like these halocarbons, it meant that enough chlorine and bromine had built up in the stratosphere for it to take decades to return to normal, even after a 100 per cent ban on emissions. So in one way the ozone story is a phenomenal success story. In other ways you could argue that we waited too long.

Climate change and ecosystems

Climate change and ecosystem degradation are highly integrated issues. They are environmental and developmental issues of course: both undermine environmental sustainability, poverty alleviation and the livelihoods of the poor. They cause significant problems for human health and threaten security at the personal, national and regional level. Climate change and ecosystem degradation put further stress on a highly stressed world. We have recently seen how fragile even a country which is relatively stable, such as Kenya, can be. Ecosystem degradation and climate change can push a country or a region that is on the borders of conflict into conflict. These are issues of both inter- and intra-generational equity. Developing countries and the poor are the most vulnerable, but with both climate change and ecosystem degradation it is largely the actions of the industrialized world that have caused the problem, and clearly the actions of today will affect future generations.

Climate change

We know that climate change is happening and there is absolutely no doubt that it is due to human activity. Atmospheric carbon dioxide has increased by 30 to 35 per cent. We are already seeing warmer temperatures and future warming is inevitable. We are seeing changing precipitation patterns both spatially and temporally. Some areas are becoming wetter; some are becoming drier. In most cases we are seeing more heavy precipitation. We are seeing higher sea levels, retreating mountain glaciers, melting of the Greenland ice cap, and reduced Arctic sea ice in both extent and thickness. We are seeing more frequent extreme weather events (heat waves, floods, droughts), and we are seeing more intense (rather than more frequent) cyclonic events such as the hurricanes in the Atlantic.

The big debate has surrounded whether these changes are due to natural phenomena or to human activity. When we plot observed temperatures against simulations of what might have been expected due to natural phenomena such as solar radiation and volcanic activity, we find that observed increases



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simply don't fit the simulations – whether as a global mean, over land or over sea, and over each of the continents. When, however, we simulate the changes you might expect with the added influence of anthropogenic greenhouse gases, the simulation matches observed temperature change. It was this type of information that led the IPCC in its *Fourth Assessment Report* to say with more than 90 per cent certainty that most of the observed temperature change in the last 50 years has been due to human activity: an increase in greenhouse gases largely resulting from combustion practices and deforestation. The crucial issue is what will happen in the future. Relative to 1990, one predicts a rise of anything from a low of 1.1°C to a high of 6.4°C, with land areas warming more than the oceans, and high latitudes warming more than the tropics. So to what degree should one adopt a precautionary approach with this type of information?

We project future changes based on plausible assumptions of demographic, economic, technological, socio-political, and indeed behavioural change. Probabilistic scenarios are not easy to do but, given a range of scenarios, it is reasonable to take the average as a best estimate. On that basis, what we expect doesn't look good – it would suggest something like a 3°C change over the next 100 years. We all know that the summer of 2003 was hot, with some 20,000 to 30,000 people in Europe dying in the heat wave – typically old people who could not get out of the high temperatures at night (it was a night-time phenomenon). There was a similar experience in the United States more than a decade ago when 600 people died. This was a socio-economic issue, particularly affecting poor people and the elderly who did not have air conditioning. As with Hurricane Katrina in New Orleans, it is always the poor and disadvantaged that suffer most from these types of events. But based on the projections, the summer temperatures of 2003 will seem like a very average summer in the 2040s and a cool one by the 2060s.

Plenty of people living in the United Kingdom might welcome warmer temperatures. With respect to agriculture, there might be opportunities for an extended growing season. High latitudes in the northern hemisphere are likely to experience increased productivity, at least with a rise of 2 or 3°C. But beyond that, we would project falls in yields in many developed regions. Of course this assumes that there will be no significant breakthrough in developing drought-resistant, temperature-tolerant, salinity-resistant and pest-resistant plants – all of which might be feasible, but can we do it with conventional plant breeding or will we need transgenics? Will transgenics live up to their promise? Even if they do

make the breakthrough, will the public accept them in light of environmental and human health considerations? These are real issues, so our projections make no assumptions about developing crops to be more climate resilient.

A moderate rise in temperatures may have some advantages for the developed world, but in many developing countries temperatures are already beyond what is required for maximum yield for most cereals, so even a slight warming will result in decreased productivity. With regard to water, we are already seeing glaciers melting all over the world – a serious environmental issue but an equally serious developmental one, as hundreds of millions of people depend on run-off from glaciers. We will see significant decreases in water in the southern Mediterranean, the northern and southern parts of Africa and in many parts of Asia. Sea-level rise will have adverse effects in low-lying delta areas, and obviously in the small island states.

Ecosystems

The five major threats to biological diversity and ecosystem function are climate change, habitat change, invasive species, overexploitation and pollution, especially by nitrogen and phosphorus. The Millennium Ecosystem Assessment looked at a number of ecological systems including forestry, drylands and the marine environment, and assessed to what extent the five main threat factors have been drivers of biodiversity loss over the last 100 years. The results were varied. Boreal forest diversity, for example, has suffered little from habitat alteration, whereas this has been a major driver of loss in tropical forests and temperate grasslands. Climate change, as you might expect, has not been a significant threat in the last hundred years to most ecological systems (with the exception of the polar regions). But the future tells a very different story. In only one ecosystem type (temperate forests) is one of these threats decreasing (habitat alteration). In all other ecosystems, the five major threats have an ongoing, increasing or rapidly increasing impact, with climate change and pollution the most rapidly growing threats across all ecosystems. If we don't get to grips with climate change or pollution, these will be the major drivers of change over the next century.

Why do we care? Ecosystem health has major consequences for human well-being, and it was this – the link between ecosystem health and human well-being – that provided the conceptual framework for the Millennium Ecosystem Assessment. We separated ecosystem services into four blocks:



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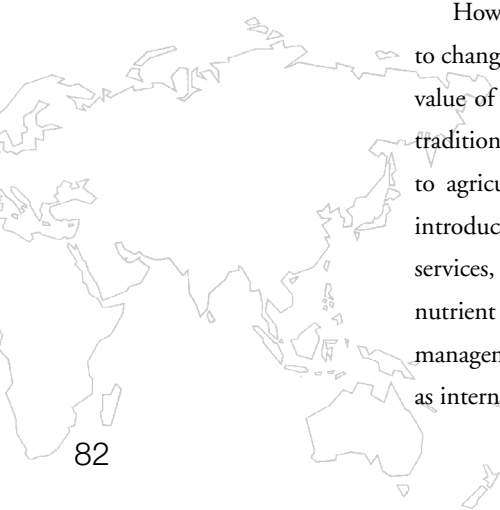
- Provisioning: food, fresh water, wood and fibre, fuel etc.
- Regulating: of climate, flood, disease and water purification.
- Cultural: aesthetic, spiritual, educational and recreational.
- And supporting the above: nutrient cycling, soil formation, primary production etc.

And we looked at the five major constituents of human well-being, as follows:

- Security: personal safety, access to resources, security from disasters.
- Basic material requirements: adequate livelihoods, sufficient nutritious food, shelter, access to goods.
- Health: strength, feeling well, access to clean air and water.
- Good social relations: social cohesion, mutual respect, ability to help others.
- And relevant to all of the above: freedom of choice and action.

Of course we have insufficient knowledge to measure these links in a strictly quantitative sense, but the framework enabled us to see where certain ecosystem services have been maximized at the expense of others. We realized, for example, that human development has mainly focused on maximizing the provisioning services – food, water and fuel – and that this has been undermining the regulating, cultural and supporting services, which in turn has undermined many of the constituents of human well-being. It is this type of analysis that – even without strict quantification – is slowly but surely influencing policy formulation in some countries.

How do we move to sustainable ecosystems? We have to put a value on them, and therefore we need to change the economic background to decision making. We need to make sure that we understand the value of ecosystem services that sell in the market place – the provisioning services – and those that traditionally have no market value – the regulating and cultural services. We need to remove subsidies to agriculture, fisheries and energy that cause harm to people and the environment. We need to introduce payments to landowners in return for managing their lands in ways that protect ecosystem services, such as water quality and carbon storage. We need to establish market mechanisms to reduce nutrient releases and carbon emissions in the most cost-effective way. We need to improve policy management, and we need to integrate decision making across different departments and sectors, as well as international institutions. We must include sound management of ecosystem services in all planning



decisions. Whether building a road, or planning an agricultural project or a water scheme, we need to make absolutely sure that we understand those ecosystem services when we make planning decisions. And we need to bring stakeholders – particularly marginalized groups – into the planning and implementation of projects. Of course we need additional protected areas, but first we must turn most of the existing ‘paper parks’ into real protected areas. We need to exchange knowledge, including that of local and indigenous groups. We need much more environmentally friendly technology, and obviously we need to move to a low-carbon economy. We need to influence behaviour through public education on why and how to reduce the exploitation of threatened ecosystem services, through establishing reliable certification systems to give people the choice to buy sustainably harvested products, and by giving all stakeholders access to information about ecosystems and decisions affecting their services.

Mitigating climate change

If we want to limit climate change to a 2°C temperature rise, then staying below atmospheric carbon concentrations of 400 parts per million (ppm) will give us a 50/50 chance. If we let concentrations rise to 550ppm then we have a 50/50 chance of limiting change to a 3°C temperature rise. The European and UK position is to try to stick at 2°C – a great aspirational goal and I strongly applaud it. However, the chances of stabilizing at 400 or even 450ppm CO₂ equivalent are very remote. So while our policy should be to aim at stabilizing at 2°C, we should be ready to adapt to a rise of at least 4°C, and we should put the planning in place now.

Stern concluded in his report that if we did nothing to reduce emissions, there would be a 50 per cent probability of exceeding a 5°C rise, and I fully agree with him. For Europe, this would probably mean summer temperatures of 8-10°C higher than normal, and for northern Canada it would probably mean summer temperatures of 10-15°C higher than normal, so really very significant warming. Stern estimated that this would be at an annual cost of anything from 5 to 20 per cent of GDP. If we were to achieve the 550ppm trajectory, with a 50 per cent chance of exceeding a 3°C rise in temperature, the cost would be around 1 per cent of GDP annually. Looking at the 450ppm trajectory, mitigation costs would be at about 3 per cent of GDP. But even then, we would only have a 50 per cent chance of keeping the temperature increase at 2°C, so we need to think about adapting to something higher.



There is no such thing as business as usual, but if we project what could happen in the future without taking time or change into consideration, we can expect something like a 60 per cent increase in greenhouse gas emissions over the next 50 years. So in order to get onto a pathway for stabilization at 500 to 550ppm, we would need a 60 per cent decrease in emissions by developed countries (relative to 2002 emissions levels) and an increase of only 60 per cent by developing countries instead of the predicted 140 per cent increase under a 'do nothing' scenario.

Have we got the technological options to achieve this? Absolutely: more efficient energy production and use, fuel switching, renewable energy, carbon capture and storage, nuclear fission, improved management of our forests and agricultural soils. We already have a huge amount of technological capability to start to move onto the 500 to 550ppm pathway, but there are also certain pre-commercial activities, like carbon capture and storage, integrated gasification combined cycle, and second and third generation biofuels, that require investment and research to bring them to market as soon as possible.

It is absolutely crucial that we get a price on carbon, whether it is \$20 a tonne, \$50 a tonne or \$100 a tonne. We need to work across all sectors, and even the modest carbon price of \$20 a tonne can start to stimulate reductions right across these sectors. By the time you get to \$100 a tonne, you can get very significant reductions.

There are many combinations of technologies that could get us onto the 550ppm trajectory, and it will vary regionally, but the one thing that is critical across the board is carbon capture and storage. Energy efficiency is a major driver, though there is likely to be a rebound effect. If you give someone in the developing world a gadget that is twice as efficient as the one they've got (or indeed might not have at all) they will probably use it twice as much. In fact if you gave the average person a car that is twice as fuel efficient as their current one, they probably wouldn't use it twice as much but, given the high petrol prices, they would certainly use it more.

Biofuels (bioethanol from sugar and maize, or biodiesel from palm oil, soy or rape seed) usually play a significant role in mitigation scenarios. But they are rarely economic. The only place that has made it really economic was Brazil when oil prices went above \$50 a barrel and they could produce sugar for less than \$200 a tonne. But in most other places, especially Europe and North America, biofuels have been heavily

subsidized. And of course there are some really serious questions regarding the environment. Do biofuels really reduce greenhouse gas emissions? As a fuel, bioethanol from sugar cane clearly does, but if its cultivation leads to tropical deforestation it actually causes an increase in emissions. Is there a loss in biodiversity? Every time you expand into a pristine area you lose biodiversity and risk soil and water degradation. There are also serious questions about social sustainability: the use of maize for biofuels has clearly contributed to food price increases, and there has been involuntary displacement of small farmers by large-scale plantations in certain parts of the world. Here in the United Kingdom, I think we have to ask ourselves whether we can truly source biofuels at the level we need under the Renewable Transport Fuel Obligation (RTFO) and the European Directive that are environmentally and socially sustainable.

Summary of the major mitigation challenges

We need a global regulatory framework involving all major emitters including the United States, China and India. It must be equitable: in other words China and India should not be under the same obligations as the United States. It must be long term: if we only have an agreement for five years after Kyoto it will send the wrong signal to the private sector, which needs to know that there will be a long-term market for low-carbon technology. If we keep the clean development mechanism that we have under the Kyoto Protocol, we need to expand the range of eligible activities, including avoided deforestation, green investment schemes, energy efficiency standards, and exploring a sectoral and programmatic approach.

A key priority will be to quantify impacts and assess costs and benefits. We have to realize that on average there are more costs than benefits, but we should exploit the benefits and minimize the costs. Investment in adaptation to reduce the negative impacts of climate change will help here, but we have to accept that whatever we do there will be some residual damage. And we have to accept that the cost of both adaptation and residual damage will be lower than the cost of inaction. Mitigation costs will vary depending on whether we are looking at an agricultural system, a water system or coastal zoning infrastructure, and we need to do a great deal of work to understand the impact sector by sector and region by region.

On the same basis, we need to establish the physical, behavioural and technological limits to adaptation – a long-term framework within a long-term goal. These would include, for example, the physical limits to adaptation on small low-lying islands, the behavioural constraints that influence

where we live and why, e.g. New Orleans, and the technological limits to the flood defences that can be constructed, e.g. the Thames Barrier in London.

We need very strict targets for developed countries in order to stimulate the low-carbon economy, and we need to bring developing countries in gradually. We need robust carbon markets that view carbon as a commodity just like rice and wheat. We need to further develop technology. We need to adapt. We need to bring deforestation in. It is not an energy issue alone. We also need to think about how to bring aviation and shipping – currently not part of the equation – into the system.

Food security

We currently have a major issue with rising food prices: rice has almost doubled in price in the last two years and maize prices have also gone up significantly. Rapid increase in demand in developing countries, especially China, has a lot to do with it, but it is not the amount of food that counts, it is the type of food. A growing demand for meat is putting pressure on grains as livestock feed. We have had some poor harvests in Australia, Europe and North America, so have less stock than normal. The increased use of biofuels – especially maize in the United States – is taking up land that was originally being used for food crops. High energy prices are pushing up agricultural input costs, and some large exporting countries have become very myopic in the use of export bans. Speculation on the commodity market has also played its part.

But is this temporary, or are we going to see more of it in the future? Overall, the agricultural sector has done a superb job. Total food production has exceeded the global rate of demographic change, meaning that food production per capita has increased. Food prices are at an all-time low despite having doubled over the last year, which has effectively brought them back to where they were in the mid-1980s. And the proportion of the world's population that is undernourished has fallen. Yet we still have 850 million people going hungry every day. Uneven distribution is the main problem: there is plenty of food in the world but the supply system isn't working. In addition, however, increased productivity has done significant damage to biodiversity, soils and water, and we now have the major contributing factor of climate change.

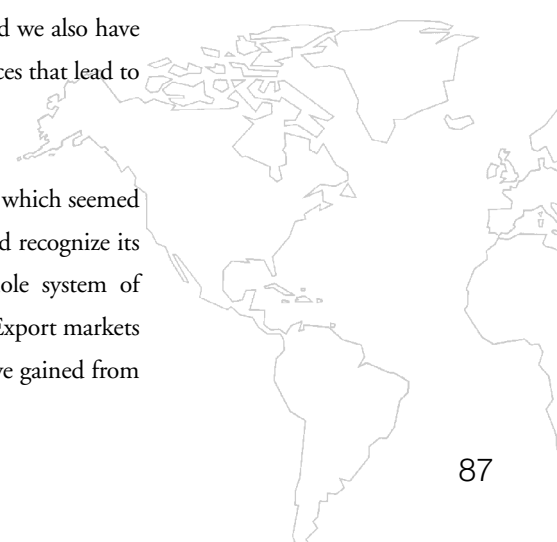
Agricultural productivity has almost doubled in parts of Asia and the Pacific, and this is what has brought a lot of people out of poverty and hunger in China. But in sub-Saharan Africa, production has

actually gone down over the last 20 years, bringing increased hunger and poverty. Even in India, where the Green Revolution was considered a major success, we still have 50 per cent of children under five suffering from malnutrition. So while the Green Revolution had significant successes at one level, we certainly have not solved the problem.

So what are the challenges?

We need to double our production in the next 25 to 50 years. We need to make food more nutritious and we need to make it more affordable. We need the agricultural sector to feed the world, to enhance rural livelihoods in developing countries and to stimulate economic growth, but it must not be done with an exclusively production-oriented focus. It must recognize food safety standards and be both environmentally and socially sustainable. There are plenty of problems: there is less labour available due to HIV/AIDS; there are endemic disease problems in Africa (malaria, cholera); rural-to-urban migration is taking people off the land; there is less water available for irrigation as demand from other sectors grows; climate change is making the arid and semi-arid areas yet drier; and there is competition for land from biofuels, roads and expanding cities. This results in major land policy conflicts in many parts of the world where there are neither individual nor community property rights. We have lost biodiversity due to mono-cropping, which undermines the genetic base for much of agriculture. There are increasing levels of acid deposition in many developing countries that have not yet got the industrial standards of Europe or North America. It is of course self-evident that agriculture has an impact on climate change and climate change an impact on agriculture. The extensification of agricultural systems leads to unsustainable forestries which leads to biodiversity loss which also leads to a loss of the genetic base, and we also have significant loss of fertility, bad irrigation systems, and other poor land-management practices that lead to the loss of organic matter in the soils, in turn leading to salinization and erosion.

After the Second World War, the only thing that mattered in Europe was production, which seemed fine at the time. But we now have to look at agriculture as a multi-functional activity, and recognize its economic, social and environmental dimensions. We have to think through the whole system of marketing and trade, which is currently neither environmentally nor socially sustainable. Export markets have created environmental problems, and while many people – including the poor – have gained from the trade system, the poorest of the poor have not.



Environment on the Edge

The academic community has helped produce some outstanding knowledge. Scientific assessments have been the corner stones of work at the national and international level to bring about policy changes regarding ozone and climate, and they are starting to get people to rethink biodiversity at a local and national level. International assessments such as the agricultural assessment are starting to turn people's minds towards what sort of revolution we need in the agricultural sector to move away from a production focus to what I would call a sustainability focus. We still have fragmented policies around the world, but slowly and surely, led by the academic community, policy is beginning to recognize the interconnectivity of all these issues.

We are moving in the right direction. But we have a long way to go: business as usual – whether it is in climate change or biodiversity or agriculture – will not work. We need a paradigm shift in all of them.



Professor Robert T. Watson

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Co-Chair of the International Scientific Ozone Assessment

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Environment on the Edge is a series of lectures given by leading international figures that examine our current relationship with the natural world and discuss what tomorrow might bring.

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