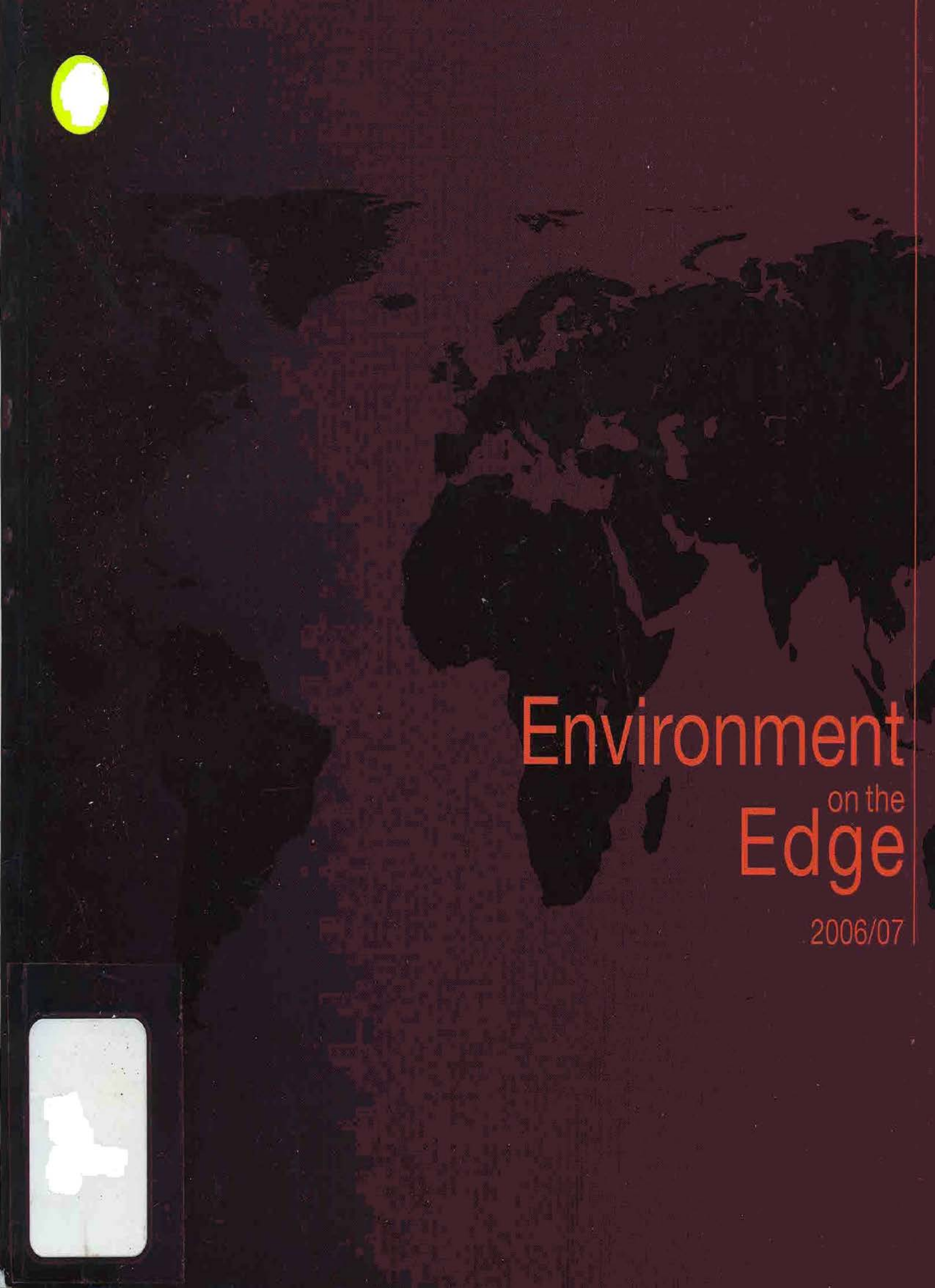

Environment on the Edge

2006/07

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Environment on the Edge

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THE UNITED NATIONS ENVIRONMENT PROGRAMME WORLD CONSERVATION MONITORING CENTRE (UNEP-WCMC) is the biodiversity assessment and policy implementation arm of the United Nations Environment Programme (UNEP), the world's foremost intergovernmental environmental organization. The Centre has been in operation for over 25 years, combining scientific research with practical policy advice.

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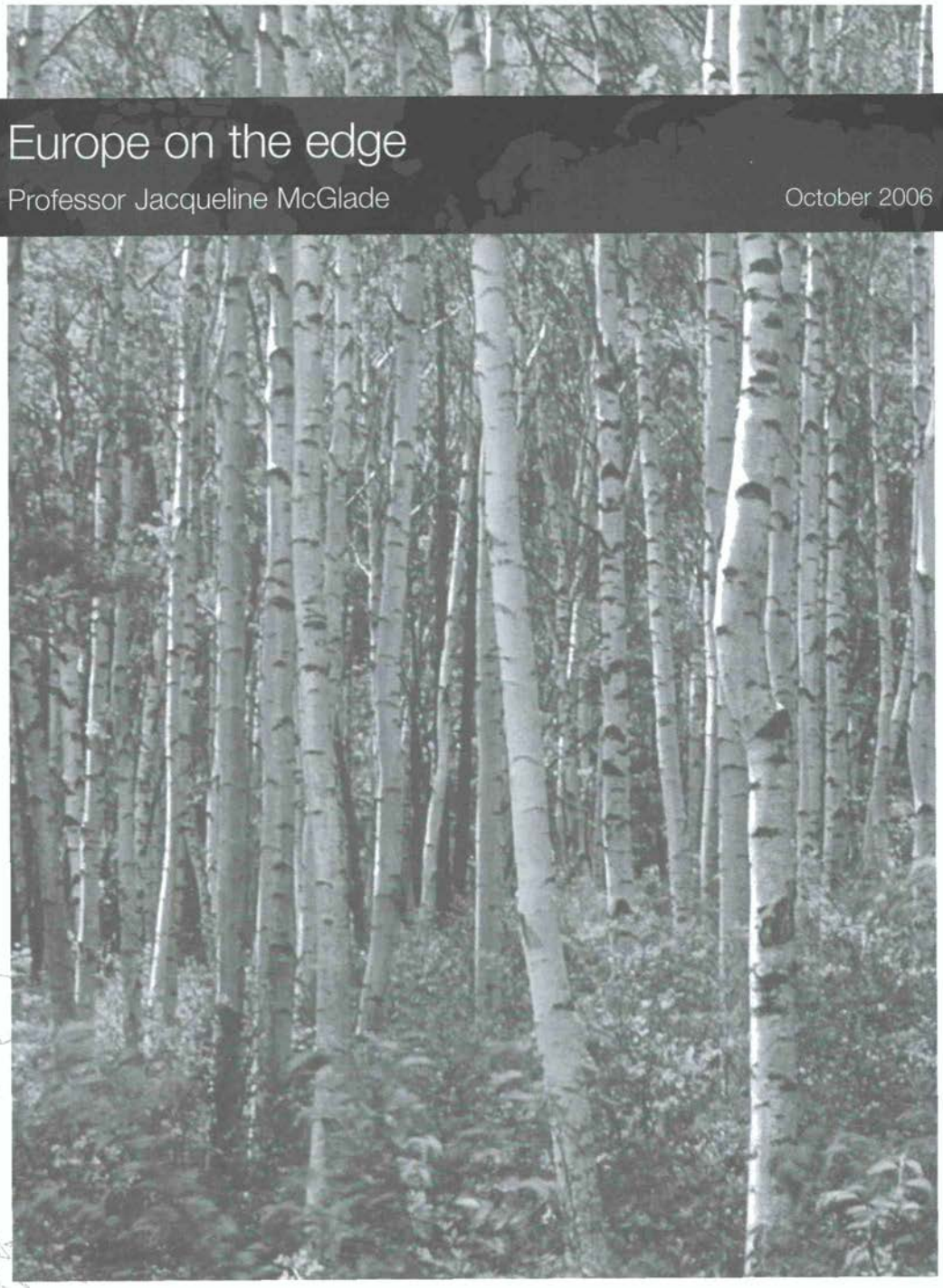
CONTENTS

Europe on the edge

Professor Jacqueline McGlade

October 2006



Environment on the Edge

The European Environment Agency (EEA) has 32 member countries ranging from Iceland to Turkey, made up of the 27 European Union member states, the countries of the European Free Trade Association (EFTA) and Switzerland. Over the years, more and more people see the Agency as a necessary pre-condition rather than an easy way into the European Union, as they not only have to put in place the environmental rules and regulations of the Union – the environmental acquis – before they are accepted, but increasingly need to report to the EEA on the outcomes. And increasingly, countries in the west Balkans, the Caucasus, the non-EU Mediterranean and Central Asia see alignment with the EEA's operations as a sign of progress.

What is fascinating about the Agency is that over the last two or three years it has grown from a body that primarily reported on the past, to one which is beginning to tackle the broader agendas of the economy, the social fabric of Europe, cohesion, transport, energy and agriculture. There is virtually no area in today's politics that is not premised on one or other aspect of the environment.

In interviews with the public (the EEA has a remit to communicate with the 450 million citizens in its member countries), the environment now ranks alongside concerns about health and education. Our task is to translate the sense of urgency the public feels into political action.

When we talk about today's pressure on Europe's environment, we are really discussing the unsustainable patterns of consumption and production that exist. Globally these pressures are being intensified through climate change, population growth and overuse of land and natural resources.

What is fascinating about the EEA is that even though its member countries range from the high Arctic to the edge of Central Asia, we can really see the impacts of this excessive consumption. So we just have to imagine how much worse the picture would be if there hadn't been 30 years of environmental legislation, bringing significant improvements to the environment and a positive change in public awareness.

Nonetheless, our ecological footprint, the draw on resources from the rest of the world, is increasing, Europe's population is ageing, and our demand on the world's biocapacity is rising. We can argue about the absolute numbers, and how the footprint is calculated, but the trend that it shows is incontrovertible – we are living beyond our means within the borders of Europe. This has happened in rather a short

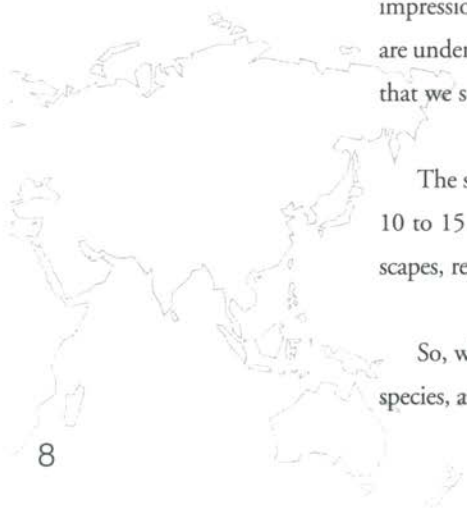
period of time – over the last 30 years. And whether we look at our acquisition of fossil fuels, our nuclear footprint or fisheries, the message holds true.

China is in much the same situation as Europe 30 to 40 years ago, and the same trends are emerging: a continuing demand for fuel and energy to keep the economy going, and the 'liquidation', if you like, of its considerable environmental assets. On a per capita basis, of course, each individual in China is using much less than the average European. Nevertheless, the large size of the population, 1.3 billion people, means that in absolute terms China's reach is beginning to dominate much of the world's biocapacity.

And the picture is the same for India. The way we are developing here in Europe, and in China and India, are interconnected. We can no longer extricate ourselves from the economies of other parts of the world.

In the summer of 2006, the European Union described itself very much in terms of its sustainable development strategy. It said, and I quote: 'the sustainable development strategy, the Gothenburg Agenda, is going to be established as the overarching framework in which economic, social, and environmental objectives can reinforce each other, and these need to advance together'.

But while the EU may have recognized that sustainability is one thing it cannot do without, it has not yet faced up to what Europe itself is really like. Every country in Europe is experiencing urban sprawl on a massive scale. Europe seen from space at night – an image with which many are familiar – gives the impression of some kind of epidemic, its lights are so widespread. Just this image should warn us that we are undermining the natural functions of Europe's territory in order to sustain an economic growth model that we see as essential to keep pace with the rest of the world.



The same can even be said of countries that are generally considered rural, such as Ireland, which after 10 to 15 years of development have become peri-urban. Roads and infrastructure are fragmenting landscapes, reshaping them to support populations with an overreaching consumption pattern.

So, what lies ahead for the environment? Today, most people live in cities. We have become an urban species, and as more and more people withdraw from the natural environment, it is becoming ever harder

to convince them that they need to protect and preserve it. We therefore need to concentrate on bringing the environment in from the edge, otherwise it will be in danger of becoming a sidecar to economic and social issues, separate even within sustainable development strategies.

It is time to think clearly about how we are going to properly value biocapacity, its underlying ecosystems and the services that it represents. We all appreciate a beautiful resort or a pristine place, but we have never really worked properly on the value of the non-use of resources, so we can get the market prices catastrophically wrong. We have also undervalued people, jobs and employment in relation to the resources that keep the economy going. If we are to bring environment in from the edge to the heart of Europe we will need a fundamental fiscal reform. Not just green taxes, but a revision of the whole financial paraphernalia, including the mechanisms through which we raise taxes and support social services.

Take the example of climate change. The signals are pretty clear that it is happening, and by now everyone in Europe has understood the need for action.

What does climate change actually look like? If you go to the margins of Europe, Greenland for example, you can almost see it happening before your eyes. In 2006 we took a group of journalists up to the Greenland ice sheet and showed them the evidence of glacial retreat. One glacier, in particular, had already retreated 10 kilometres in five years at a point where it was 2 kilometres thick. It is at the margins of Europe that climate changes can be seen clearly, but there is also evidence of change in its heartland.

In Finland, in an area just north of Helsinki, a glacier has completely disappeared. (I think there was an article in *Le Monde* suggesting that photographs of the area were merely alarmist.) But the reality is there to be seen. Europe is suffering. Paris was unable to cope in the summer heatwave of 2003. Huge air-conditioned tents in the city were just not enough. Whether it was 23,000 or 32,000 extra deaths that resulted, it was too many. And people remain at risk because governments have continued to regard heatwaves as unusual and even unexpected.

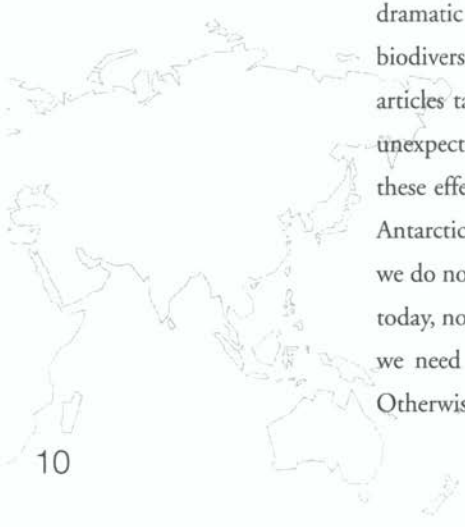
But such events can no longer be seen as one-off episodes. Indeed, after three years of summer heatwaves we have become aware of the risks in many countries in southern Europe. But floods, fires and

droughts still take people by surprise. And there are many, sorry stories about the ways in which humans and other species have been exposed to more risks through unsustainable growth patterns. Had governments been aware of the costs of the ensuing losses, they might have been prepared to make the necessary changes.

We are beginning to see some movement in the transition from simply coping with the unexpected to dealing with the expected. Here public opinion is ahead of political rhetoric; and bringing environmental concerns into the economy is certainly made easier when it is on the back of catastrophic losses.

An example of this is in Spain, where in the face of desertification in the south of the country, the environment minister decided that all information related to water licensing and abstraction should be published in the public domain: every farm, field and crop; how much a given farmer receives in subsidy; and the amount of water licensed for abstraction. Of course this has caused an enormous debate in Spain because it is possible to see that there are too many tourists, too many Europeans with second homes, too much irrigation and not enough water. Questions that have to be answered include: How much water is there? Is there less than before? Why do certain people get access before others? Can water be transported from other areas? For the first time in post-Franco Spain, there is open public debate about access to a natural resource and its absolute price. But it has taken the impending spread of desertification for the debate to get going.

In the coming decades, many types of thresholds or tipping points will be crossed. I mentioned the dramatic changes in Greenland, but there are many other more subtle changes taking place, including biodiversity losses and altered agricultural patterns. The press in the United Kingdom has been full of articles talking about late blooming, early blooming, early arrival, and all sorts of species turning up unexpectedly. Signals of change are coming in from all directions across the natural world. Of course, these effects will be swamped if the speed of global warming continues apace, and the Greenland and Antarctic ice sheets were to melt with an associated rise in sea-level of up to 12 metres. But at this stage we do not want to be alarmist, as this is not really going to help. What we want is for people to engage today, not to have a 2020 agenda, nor a 2050 agenda, but a 2010 agenda. We want political targets and we need them to be faithfully acted upon. We want to mobilize people towards those objectives. Otherwise all will be lost.



Unfortunately, a lot of decision making in Europe gets usurped by the concept of subsidiarity. The United Kingdom, for example, often talks about Europe interfering, sending clear messages not to meddle in national affairs. But such large environmental issues have nothing to do with national sovereignty. They are European and global issues, and subsidiarity will not get far in tackling them. This is happening at every single level, resulting in an inability to focus on the relative and relevant action that is required to mobilize people globally.

We tend to respond to major events very effectively. Hurricane Katrina led, if a little belatedly, to a massive inundation of support, with money pouring in and people trying to fix things. But an accumulation of smaller events can cause far more damage and entail far higher accident and death rates. Reacting in an *ad hoc* way means that we lose sight of the connectivity of events.

There is much talk in the scientific world about weather-related events, whether there are more of them, or less, and whether they are more intense. It is important that politicians do not miscommunicate this evidence, but work with scientists to knit it all together and achieve a coherence in our actions. It is worth reminding people how connected the planet is, something that the IPCC (Intergovernmental Panel on Climate Change) community has been working hard over the years to achieve.

Our patterns of consumption must also be addressed. Otherwise we will end up with a lot of people, not just within Europe's borders but all over the world, becoming marginalized, unable to participate in what – in principle – could be a very healthy and wealthy life, with access to water, education, etc.

But by working in a reactive way we actually fail to do four major things. We fail to recognize the very real dangers of continuing on our current unsustainable course. We fail to plan for the future but instead plan with reference to the past. We fail to use investments for improvements, seeing them merely as strategic platforms. Worst of all, we fail to see the economy as a means towards more dignified goals but rather see it as an end in itself.

Even in the face of climate change, and knowing that its impacts will be felt throughout the world, it is still really hard to mobilize people to work together. All of us know, within the press, amongst the public and at national level, that there is a great desire to move forward. But vested interests at the highest

level are blocking the kind of global movement that we want to see. No matter what evidence there is of climate change and its effects, some parts of government are just unable to react coherently and make the kind of shift in governance and policy making that we need.

The most disturbing part of it is when the potential loss of human life and well-being is dismissed on the grounds that people are poor anyway, or are old and going to die so their pensions will not have to be paid. These are some of the appalling ideas that are voiced in debates, not just amongst politicians and business but amongst senior civil servants. This kind of bean-counting approach to life will get us nowhere in moving the agenda forward.

So, what should we do? I believe we have come to a moment in time when there is so much going on that we just have to sit down and think about it all. We have globalization. We have world trade issues but are failing on the Doha Round. We have climate change. We have massive commercial activity with China and India. We have an energy crisis. We have wars. In fact, so much is going on that there is a sort of fatigue. But actually I am an optimist: instead of just letting it float us away, we need to tackle it head-on.

World trade is driving consumption inexorably to a point where we will not be able to sustain the kind of lifestyle that we currently have. And there will be constraints. Cheap airline prices, for example, will disappear. We have really got to think about the instabilities in the system and identify the crisis points, isolate them, identify solutions and have the necessary debate about what to do next.

Let us take fuel as an example. Think of the European flag; in proportional terms, the blue could be said to represent our consumption of petrol and the yellow our production of petrol. This is not sustainable, so why has it happened? The biggest source of growth in energy consumption is in households. The EU commissioner for energy recently announced far-reaching policies related to the 'stand-by' mode of household appliances, asking industries to introduce energy-efficient models that could reduce Europe's demand by 20 per cent by 2020. Such a saving represents EUR120 billion of expenditure, and it makes sense. If we achieved it, based on past experience, Europe would be leading the world in that particular sector. As the world's largest economy, we know that China and the United States, and any other country manufacturing such products, will conform to European standards. One way or another, we lead the rest of the world by having very high regulatory standards.

So, isn't it good for everybody? Well, no. The sectoral response is that it will require too much change and cost too many jobs. We get piecemeal 'lobbying', especially at the national level, when actually we need to work collectively. In reality this is a major opportunity to put Europe's industrial sector at the forefront, able to respond to the global challenge and perhaps make us slightly more energy secure. So I have been very happy to see that all the commissioners, even Enterprise and Industry, support the proposal.

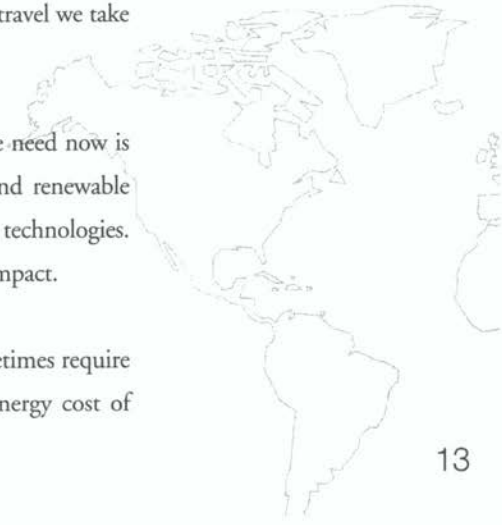
There are some things that can be done more effectively at a national level than at a European or global level, but energy is not one of them. We have an unstoppable consumption process and very aggressive companies. A well-known European furniture company, for example, sells enormous amounts of products that are manufactured in China and elsewhere and then imported to Europe. The public is largely unaware of this and believes that the company is dominated by green products. Labels carry messages such as 'Designed and quality assured in Sweden', but then in very small print 'Made in India', 'Made in China', 'Made in Egypt'. Steel coat-hangers are just one of the many items that we transport around the world. We are doing the most crazy things to perpetuate our unstoppable consumption patterns.

Another example: herring are taken out of the water by the Faroese fishing fleet, then shipped to China to be filleted, then brought back to the Faroes and put in a plastic bag labelled 'From the Faroes', and sold to the European market. This is only possible because the shipping company offers round-the-world transport for EUR6 per tonne. Competition means that goods and services are getting cheaper.

In addition, our leisure time is leading to an extended form of consumption. When we travel we take our consumption patterns with us, exporting them all over the world.

I mentioned earlier the well-known image of Europe's lights seen from space. What we need now is not lights but enlightenment. There are many who are really excited by eco-efficiency and renewable energies. Most governments love to talk about how much they support renewable energy technologies. And it is largely positive because they will help the energy sector reduce its environmental impact.

But what governments do not do is life-cycle analysis. Energy-saving technologies sometimes require more energy to generate a product than they will save in their operation. The actual energy cost of



construction and transport can mean that systems have to operate for 50 or 60 years just to reach the neutral point. So we have to make sure that, as we assess different technologies, we see a full account of the impacts over the entire life cycle. If we had a formal, transparent and widely available system for this type of accounting, there would be no reason why any technology could not be compared to see whether it is worth investing in.

One interesting thing about all this is where we apply subsidies, and where our taxes actually go. Take the energy sector: in 2004 traditional sources in Europe were subsidized to the tune of EUR32 billion, whereas renewable sources received only EUR5 billion; roughly translated this is EUR82,000 per German coal miner. Clean technologies remained largely outside the frame. In Sweden, however, the major power company decided to move into carbon sequestration through its experimental 'clean' coal-powered plant in Germany.

The company made a fundamental decision to operate the most resource-efficient power station possible – in construction and operation – regardless of subsidies. Although a fundamental question of using coal in a time of greenhouse gas reduction remains, everyone can benefit from the type of thinking behind this business decision. It is a very Swedish approach, where the adoption of the concept of resource accounting and 10-year tax subsidies to help transform businesses have been the making of many companies.

These possibilities exist for all of Europe. So if we really want to address issues of energy security and the environment, we should create clean technologies and establish renewable energy sources inside Europe, and ensure that the transfer of technologies is facilitated and even subsidized worldwide. However, it seems that the vested interests of the more traditional parts of the energy sector make it more likely and less painful to fix problems of energy production elsewhere than take action on domestic measures in Europe.

Let us return to the issue of Europe recognizing its responsibility in the destruction of other people's natural environments. This is not a minor issue. It is affecting the environmental quality of the lives of many millions of people all over the world. It is no longer about one nation-state investing in a particular technology, such as carbon sequestration technologies, to get ahead in the market. It is about the need to

cooperate at a European level, and in tandem at a global level, and agree on how to invest our public and private funds for the greatest global good.

One example of where this needs to occur is in relation to the Clean Development Mechanism, an instrument of the Kyoto Protocol. This enables signatories to sequester carbon through projects in the developing world; some very interesting operational ideas have taken root but they will not deliver anywhere near what is needed for climate change mitigation. And by fragmenting our responses to the problem of carbon dioxide emissions, we have lost the economies of scale of any investment.

Slowly, the debate on how to bring about fiscal reform across the world to meet some of these global agendas is taking place. Many people understand what a sound environment is. They do not want to live near polluted landscapes or on landfill sites; they want to be sure of the quality of the water they drink. Yet across Europe we see more and more people living in urban ghettos, exposed to an increasing burden of chemicals, narcotics and various other substances, and far away from nature. In the end these factors will lead to a decline in life expectancy despite improvements in general health care. In the disconnection and hence overuse of our natural capital, we are in danger of creating a very empty world.

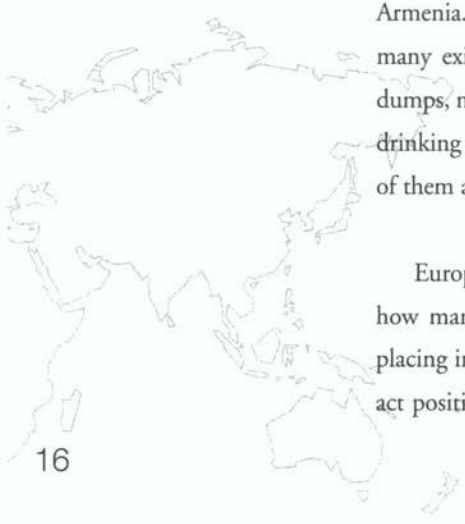
So how do we get to a fuller world? We need healthy happy people living in a quality environment, and to achieve this we have to engage with everyone, especially business. Recently, the chemicals industry went through a long battle over legislation requiring them to register all chemicals produced over a set volume, even though this would be in the interests of their consumers. Conversely, in an earlier decade when there was an oil crisis, this same sector showed that it could radically restructure itself to reduce its energy requirements and hence costs. Obviously, business must make sense in business terms, but it also has to be coupled with the wider sense of real social responsibility. This is what it means to bring environment in from the edge. It is more than just a question of GDP.

A recent study by the European Science Foundation, led by Sir Michael Marmot and his team at University College London, looked at what makes people live a long time. Some of you may have read the books: *Status Syndrome: How Our Position on the Social Gradient Affects Longevity and Health,* or its easy-to-read version *Who do you think you are?,* which describe the famous *Whitehall Study* and the analysis of

life expectancy in civil servants with stable jobs. Despite the outward appearance of evenness in well-being, civil servants just one grade apart had on average half a year's difference in their life expectancy. The authors showed that social status directly affects life expectancy. Worse than that, if you are not connected to other people in everyday life you are potentially at risk. For example, if you compare a very well-off individual living in isolation, to a 'nice old lady', head of the knitting club in a rural community, you can almost guarantee that she will have a longer life, not so much because she comes from a rural community but because she is part of a club – she is respected, she has a place. Study after study has demonstrated that isolation is actually one of the most negative forces in today's Europe.

In fact GDP is not as closely associated with well-being as you might expect. What really matters is how we live our lives, our social cohesion and the way in which we come together to do things. Across Europe though, this understanding is often missing. Greece does not recognize it in its health plans; Spain used to be concerned but no longer; France, Italy and Lithuania are beginning to be concerned – the riots in France have certainly triggered this; and Finland, the Netherlands, Sweden and the United Kingdom have now got a structured approach within their health authorities. We are slowly beginning to see how the fabric of life is every bit as important as GDP as a social indicator.

Talking about social isolation, so much of this occurred when the Soviet Bloc broke up. The same is happening, in fact, all around Europe's borders. In the southern Caucasus – Georgia, Armenia and Azerbaijan – which had a population of 16 million in 1991, around 4 million people have become displaced over the last years, with half of them in Azerbaijan and the other half split between Georgia and Armenia. Three million people are now either displaced, or are economic and environmental refugees, many existing in temporary accommodation and camps, surrounded by nuclear waste, ammunition dumps, minefields, landslides, deforestation and contaminated soils, with limited access to sanitation and drinking water. It is a catalogue of collapse. But as these people are also our neighbours, of course many of them are trying to migrate into Europe.



Europe's borders are under immense pressure; you only have to look at the Frontex statistics to see how many people are trying to enter, both legally and illegally through human trafficking. This is placing increasing demands on the environment in particular border areas. It is imperative that Europe act positively towards these issues within its neighbourhood programme, and not adopt a head in the

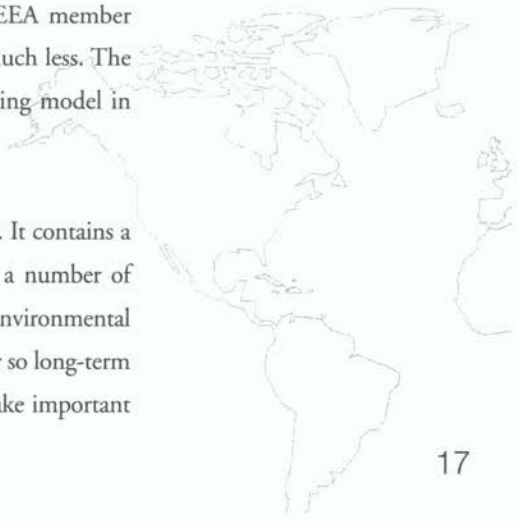
sand approach. But at the same time, guidance is needed on what to do: what works, what does not, how to deal with people's needs, and ultimately how to clean up environmental damage when governments collapse.

Within Europe's borders we have a single internal market in which anything can be sold (often undersold if it is a natural resource) and competition encouraged. There have been some positive effects of this, for example in the United Kingdom people became much more careful when water was metered and priced. Of course this will not always be the case; under certain conditions when there is no water, and governments have to intervene, then prices will not reflect use or scarcity.

We have to recognize that even increased use of resources locally is creating significant environmental pressures and will ultimately affect all of us because of the internal market. Because of this, we will somehow have to reassess our capital assets, not just buildings, trains, railways and roads, but also our natural assets of water, land, soil, biodiversity and air.

So how do we make the shift in emphasis? First we must reform our fiscal approach and move the tax incentive away from producing bad things to looking after good things – people, plants and animals. We should offload the tax burden from labour and shift it towards the inefficient use of resources, both materials and energy. This is the conclusion we came to in the EEA in our most recent state of the environment report.

One of the most interesting tables in the report shows the tax systems of all the EEA member countries, and you can see that some use environmental taxes extensively, whilst others much less. The conclusion we arrived at is that the obvious way forward is to revise our economic trading model in Europe, and inevitably globally, to one which takes the environment into account.



The report also looks at how political targets are set and whether and how they are met. It contains a league table of environmental performance that makes pretty uncomfortable reading for a number of countries, for there are many unmet targets, as well as targets that do not deliver the environmental outcomes expected. Politicians try to do a great deal, but their goals tend to be short-term, or so long-term that those responsible for them will no longer be in power when they fall due. Thus to make important

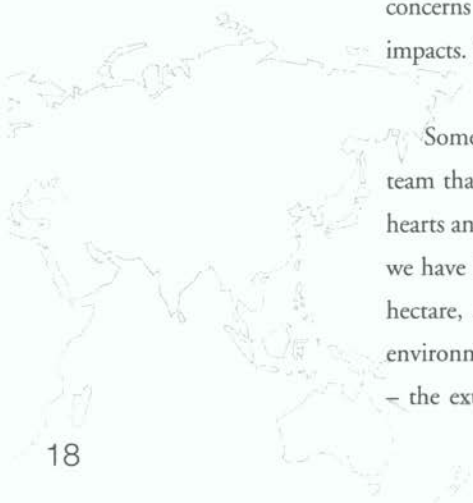
environmental progress we need to set not only the right kinds of political targets, but also the right kinds of checks in order to hold governments to account.

In Europe we have more than 450 environmental reporting obligations, so it is not surprising that many governments and businesses want to cut back on regulation. On the other hand, streamlining could place many of the more necessary legal elements needed to protect the environment, and in turn people, at risk. Whether we like it or not, history has shown that the only way to protect the environment is through societal pressure backed up by a regulatory framework. If we give up on environmental legislation and rely on voluntarism, the quality of the environment will very likely deteriorate.

But we can be smarter about how we plan things. The Urban Waste Water Treatment Directive, the most expensive piece of environmental legislation in Europe, was implemented 30 years ago in Denmark through an end-of-pipe solution, letting all the water go through the sewage plants and only then cleaning it up. The Netherlands went the other way, cutting down the amount of water entering the system. Today, Denmark spends six times more on water processing than the Netherlands. If you go to the source of the problem you are likely to find better and more cost-effective implementation.

Better regulation, as some countries have termed it, does not mean less regulation. This is what we have recognized in Europe – but we can be smarter and learn from the solutions found by each other.

In Europe the long-term picture is covered by what is called in Eurospeak the Lisbon Agenda. This concerns bringing transport, energy and agriculture together, and looking at long-term synergies and impacts. But I think more recently we have moved beyond Lisbon, perhaps even to a planetary dimension.



Some of you may have seen this explored in the scenario activity at the EEA called Prelude. The team that created it has won a number of prizes for their work, but more importantly it has won the hearts and minds of people in ministries and parliaments as well as among the public. For the first time, we have been able to map the future of Europe on the basis of different economic models, hectare by hectare, and look at what will happen in relation to urban sprawl, transport, energy and the environment. In response to climate change, some very sobering trends emerge. Large parts of Europe – the extreme northern and southern areas – will become largely uninhabited, with 'climate change

refugees' moving into the middle of Europe; and it will all happen rather more quickly than many of us would like to contemplate. The simple message for the future is that we will no longer be able to disassociate the way we produce our food, fuel our activities and move ourselves around, from the ecosystems that support us.

In the end we have to help people to account for themselves. Fortunately, there is a quiet revolution under way that will help us to do this. The statistical offices of Europe, actually of the world, are now working to agree formally the inclusion of resource accounting in the main treasury accounts that calculate GDP and tell countries how their economies are doing.

In two or three years time you will be able to see not only how money moves around but also how water and other resources are used to support the economy. We know that to date we have not been very successful at placing an appropriate value on many natural resources. So being able to account for everyone's resource use in a transparent way, mundane though this may seem, could help change people's attitudes. It will certainly help to bring the environment from the edge into the very centre of our lives.

I also hope that such a move towards more transparency and accountability will mean that places such as the Arctic can be protected from the vested interests of the countries adjacent to it, who are racing ahead to claim rights over as yet unknown resources. And that instead, we can have a reasonable approach to saving what is probably the last pristine ecosystem in the world.

As they say in indigenous communities, it is not about sustaining one generation but about sustaining seven generations. But to think seven generations ahead we would have to significantly change the way we do things today. I hope that I have given you some persuasive arguments as to why we should do this and how the new accounting for resources could help us to bring the environment in from the edge to the centre of our thinking.

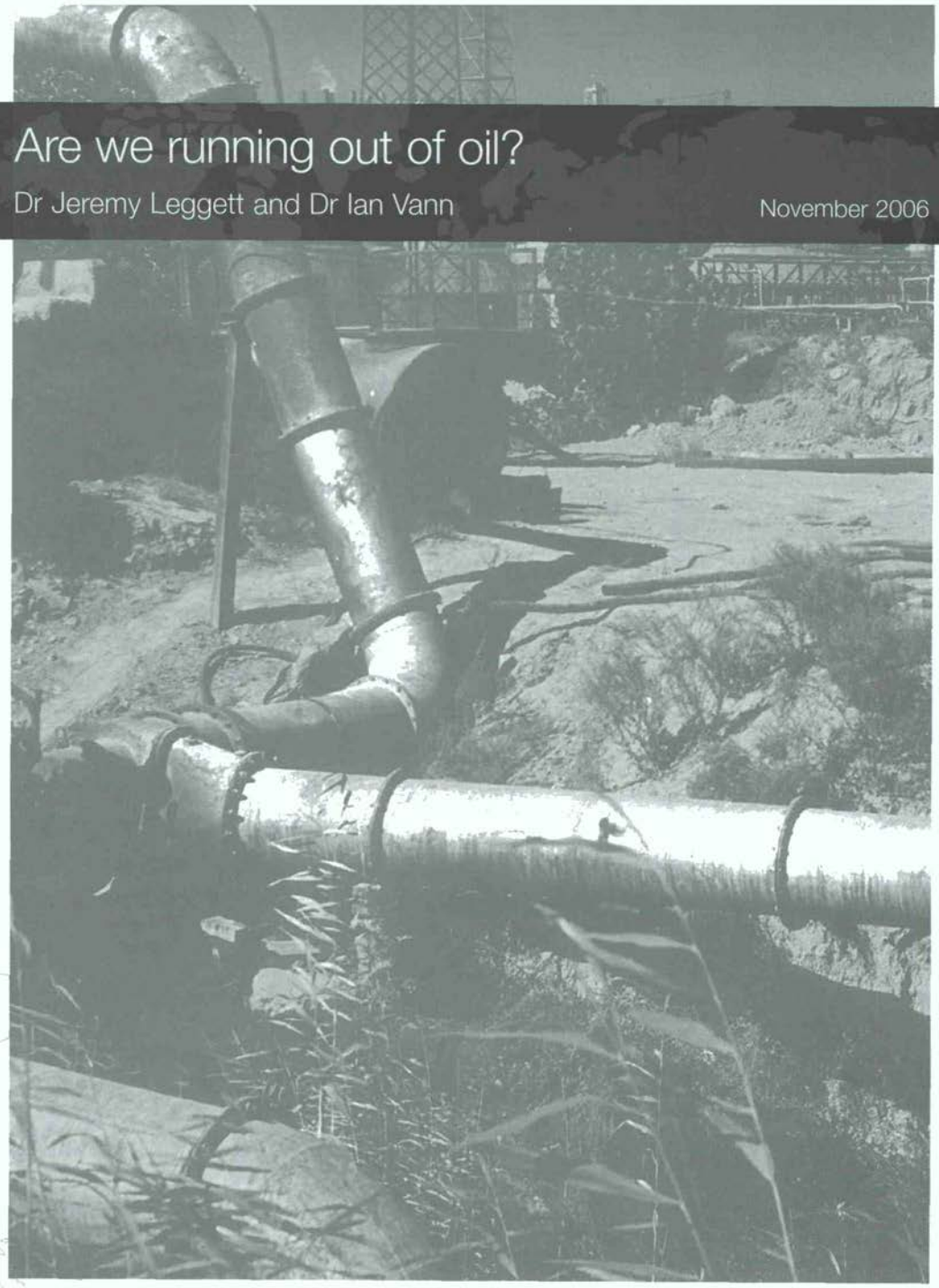
Professor Jacqueline McGlade

Executive Director of the European Environment Agency

Are we running out of oil?

Dr Jeremy Leggett and Dr Ian Vann

November 2006



Jeremy Leggett

Environment on the Edge

Oil is not actually going to run out – some will of course remain in the ground. But in practical terms it is clearly finite. The real issue, however, is about the transition from a time of increasing – and generally cheap – production, to a time where we have gone past the peak and into decline. Are we already there? How fast is the decline going to be? And what will this do to a global economy that we have collectively allowed to become oil-addicted?

Some people – the 'late toppers' – see the peak of production happening in the 2030s. Lord Brown often says in his speeches for BP that 'we have got at least 40 years of supply', and most oil companies believe this and, of course, all of OPEC. There have been some interesting adverts recently which could be interpreted as whiffs of doubt, particularly from Chevron. But almost all financial analysts and journalists believe that peak production is some way off.

The implication is that economies can in principle continue to grow, that there will be no dislocations, and plenty of time to develop alternatives. This is where the global warming and oil supply issues conflate, hence the BP/Shell type of approach. Renewables are important, and we are making progress, but are we displaying the entrepreneurial zeal that we have shown for a century on the hydrocarbon frontiers? We are not because we think we have time.

There is another camp that is still decidedly a minority. We are the 'early toppers', who see the peak of production occurring during this decade or, more likely, in the early part of the next. The key thing is not actually when this happens, but when the market will wake up to it. The 'early toppers' are a growing number of dissident experts, mostly oil company geologists, some futures traders and some financial analysts and journalists.

The implications of an early peak in production are not good. Economies will be dislocated, and even passionate advocates of efficiency and renewables like me cannot construct a scenario that allows time to develop alternatives. I really hope the analysis is wrong, and am constantly on the lookout for feedback to show that there is a flaw in it. But if the analysis is right, then, as the Department of Energy Office of Naval Petroleum and Oil Shale Reserves put it: 'The stakes are large. A serious demand-supply discontinuity

could lead to worldwide economic chaos.' They are desperate to get oil out of the kerogen in the oil shales to keep the US Navy afloat. And here's another interesting remark: 'We are not good at recognizing distant threats even if their probability is 100 per cent. Society ignoring this peak oil is like the people of Pompeii ignoring the rumblings below Vesuvius.' This is heady rhetoric. It comes from no less a figure than James Schlesinger, former US energy secretary.

I spent most of my professional career as a creature of the oil industry. I worked on oil source rocks in and around the industry and was funded by BP and Shell, among others, at Imperial College. Admittedly this was a long time ago. But as my research was on climate change – and I hope we will touch on climate change in terms of the conflation of these problems – I worried because I felt I understood a bit about the climate cycle. So I left the oil industry and became a campaigner at the climate talks. I believe that if there is a solution to climate change, it will come not from governments but from a nexus of industry and consumers. I have decided to join that world.

I want quickly to put the argument for the early peak of production in a historical context. Many people new to the oil industry find it amazing that the peak of discovery in the United States, the year that the most oil was discovered in the lower 48 states, was 1930. The oil industry was a fully integrated one at the time of the First World War.

In 1956 one of our heroes in geology, M. King Hubbert, who worked for the Shell Research Laboratory, predicted that US production would peak in 1971. He was treated pretty shabbily: Shell insisted that he ditch his paper, but he went ahead anyway, and was vilified for his pains by the US Geological Survey. Meanwhile, US oil production did in fact peak much as Hubbert predicted. Does that extrapolate to the whole planet? It does in a way. There was a peak of production in America and there will be a peak of production in the world. And things will have to change, as they did in America.

When was the peak of oil discovery in the world? It was way back in 1965, before England last won the World Cup. The first oil crisis was in 1973 at the time of the Yom Kippur war, and this is important for its economic ramifications. There was only a 9 per cent reduction in global supply for a very limited period, but a horrible recession nonetheless followed. The second oil crisis took place in 1978 during the revolution in Iran, followed by Saddam Hussein invading one of his neighbours

for the first time. This crisis lasted a bit longer. Demand went down by about 4 per cent and three things happened that don't pertain today.

First the Saudis could – and did – turn off the taps. Second, we did not live in a 'just-in-time world': stockpiles, both national and corporate, could be used. Third, oil was entering the world market from newly discovered provinces in the North Sea and Alaska. So the crisis blew over and, from then until recently, we have had relatively low oil prices.

That in itself is an issue because of investment in the infrastructure. M. King Hubbert was right. This is the time to reflect on that steep downturn in the lower 48 states. There are arguments that secondary production enhances overall production, that all sorts of things can be done to lift the average of 30 per cent delivery from an oil field to 60 per cent or more – we can drill horizontally, for example – and this will solve the problem alongside finding new oil fields. But with 20,000 horizontal wells drilled, mostly in the United States, none of these techniques have made a blind bit of difference to the US downturn. To be polite about it, the downturn has shaped US foreign policy and therefore our world because they got it wrong. I am not going to elaborate on this: as you can imagine I could, but I think that is a debate for another occasion.

Colin Campbell and Jean Laherrère were the first oil industry 'early toppers' to speak out with their paper in the *Scientific American*. This was when the first warning sounded really loud and clear. Meanwhile conventional oil discovery was on a downward slope, even while there was a big upturn out in the North Sea and on the north slope of Alaska.

And we are still going down. It is not since the early 1980s that we have discovered more oil in a year than we have actually used. So this is the concern: 50 per cent of the world's oil comes from its hundred biggest oil fields. All of them are over 2 billion barrels in size, and all of them were discovered more than a quarter of a century ago. The average size of an oil field discovered today is only 50 million barrels, less than a day's global supply at current rates of demand.

Meanwhile, how reliable is BP's table of 'proved reserves' in their annual bible of energy production, the *BP Statistical Review*? These reserves are described as proved without the use of

inverted commas, and if you look at the compilation from the Middle East and the rest of the world since 1970, you might wonder what there is to be concerned about. Reserves appear to have gone up and up, from 600 billion barrels of proved regular oil reserves in 1970 to over 1.1 trillion in 2003. But if you read the small print in the *Review* you find that these are not BP's estimates at all. In fact, as the company explains in a footnote, it merely reproduces the data from various official sources.

Our concern in the community of worriers is that in the 1980s lots of oil was reportedly found in the Middle East. But there are some interesting statistics from the countries concerned. Kuwait started massaging the figures in 1985, suggesting that their reserves increased dramatically overnight. (Reserves of course are in the eye of the beholder – it depends which geologist you talk to.) They went up from 64 to 90 billion barrels. Then a couple of years later they went up some more. That was too much for OPEC and most of the other states. Iraq jumped from 47.1 billion barrels to 100, and figures for other OPEC countries made similar leaps.

This is an interesting trend. Most of these countries have 'discovered' exactly the same amount of oil every year as they have produced – something of a coincidence. In 1982 they agreed that their quotas would be tied to the size of national reserves, and the massaging of data started in 1985.

The point is this: these proved reserves would not stand up to scrutiny in any court of law and we have not been in to verify them for a quarter of a century, since the oil industry was nationalized in many of these countries. If you look at the 2005 G8 statement, the finance ministers say (and I paraphrase): 'Please could we come in and look at your largest oil fields, because it is really rather important considering that the global economy has been predicated on all this being as we think it is.'

So with a falling expectation of future discovery, and a rising expectation of future production, the curves just don't match. The doubters – ASPO, the Association for Peak Oil and Gas of which I am a member – think there is going to be a big mismatch, so rather than a rise in production with a distinct peak, there will be a kind of plateau where production flattens out for a while before starting to go down.

Let's look at the discovery rates for the giants, the oil fields of 500 million barrels or more: there were 16 in 2000, nine in 2001, two in 2002, one in 2003 and none in 2004 (*Petroleum Review*). But with

84 million barrels a day of global demand, 500 million barrels is still less than a week's supply. Bearing in mind that demand is growing at 2 or 3 million barrels a day, and we are depleting capacity at 4 to 5 million barrels a day each year (it could be a bit lower, but this is what EXXON will tell you), we need to find 6 to 8 million barrels a day of new oil annually to meet the combination of demand and depletion. This is new capacity, and even if we went out and found a big oil field today, it would be around seven years before the first oil came onto the market.

Any potential there might be in heavy oil is pretty well cancelled out by the downturn in regular oil, so any increase in hydrocarbons beyond 2010 is only achievable through natural gas liquids and gas itself. But even with an increase in gas production, and notwithstanding the geopolitics that half of it is in Russia and Iran, you get a combined hydrocarbon peak in 2015. We are not geared up for this and it is difficult to imagine the landing being a soft one.

If the analysis is correct, this monster is just around the corner, and in my view this is what we should be worrying about. It will have an enormous effect on the traders in London and New York.

Finally, I would like to close by discussing two other views because this is such a fast-moving debate. In the past year it has gone from being a 'hobbyist' issue, as people unkindly called it, to a mainstream debate, reaching the front page of *The Wall Street Journal* amongst others.

If demand continues to grow as expected, with China and India economically on course, the 6 to 8 million barrels a day of new oil that we need to find is equivalent to one Saudi Arabia's worth of capacity every year and a bit, but in 2005 we managed only 3.7 million barrels a day. The meeting of growing demand with expanding supply 'cannot be done indefinitely; it is not sustainable', as was observed by Dr Sadat Ibrahim Al Husseini, former head of exploration and production of Saudi Aramco in an interview with *The New York Times* in August 2005. He has gone a bit quiet since then, but this is a gentleman who essentially ran exploration and production. He was on the board of Saudi Aramco for many years and has just recently retired.

Then there is the view of the IEA (International Energy Agency). They have downgraded the way they think demand is going, but nonetheless made the point that non-OPEC countries will pass their

peak in production within a few years. They also point out that we will be relying on Saudi Arabia, Iraq and Iran for growth in supply to meet projected demand. But are we going to get it? They calculate that a $20 trillion investment is needed by 2030. This is of course total energy, not just oil. But we are not investing at anything like that rate, and any apparent surge in investment in oil is illusory because of soaring drilling costs. 'This energy scenario is not only unsustainable. It is doomed to failure.' That was the view of the Secretary General of the IEA in late 2006, an agency set up to promote fossil fuels.

For reference I recommend *The Carbon War* on the history of the climate talks, and *Half Gone*, a commentary on this debate up to the time it was published. My closing thought is that in *The Carbon War* I describe the history of the debate that we had in the climate change community with the oil industry and BP. I am sure most people know that BP was the first company to break ranks and say '*Mea culpa*, Houston we do have a problem. These environmentalists have been right. By the way all the people from NASA and NOAA and the Met Office, and everything else, they are right.' I believe that paraphrased statement, made in 1998 by Lord Brown, actually allowed Kyoto to happen. BP's view of this problem is very important, and that is my introduction to my debating partner.

Ian Vann

I almost feel that we can go home now. I agree with everything Jeremy has said when it comes to the underlying information. I won't argue with his data. What I will argue with is what it means, and I will go right to the conclusion.

The future of oil supply is as much about politics and the ability of an economic system to operate as it is about the resource itself. And today that ability is constrained by all kinds of political forces. But I would also assert that a peak oil hypothesis is not actually supported by the data. The reason that I am as passionate about stating the other side of the case as Jeremy is about stating his side is that I believe that wrong information will lead to bad decisions. As Jeremy pointed out so powerfully, if decline sets in in five years time there is no obvious solution to the problem, and the actions that people take now could have catastrophic consequences.

A Campbell peakist – as mentioned by Jeremy – would say that peaking will occur around 2010 and then drop away, with a total of 2 trillion barrels under the curve. Others, of whom I am one, would say that there is rather more oil underneath that curve. It is the fundamental notion of the cumulative resource underneath the curve that actually defines its shape.

Nobody denies that ultimately it will turn over. The issue is when. There is little doubt about what has already been produced – around a trillion barrels. Reserves too are quoted at around a trillion barrels, so it does appear to be half gone. But what is quoted as reserves depends on people's plans.

Exploration could reveal perhaps 0.25 trillion barrels, perhaps 0.75. As you apply new technology and attack the amount of oil that is left in the ground, existing reserves could grow by anything from a low-case scenario of 0.5 trillion barrels to a high-case scenario of 1 trillion barrels. And non-conventional oils such as heavy shale oil, oil sands and so on, supply another range of outcomes – from 0.25 to 1.25 trillion barrels, depending on what people do.

In comparing today's world with M. King Hubbert's 1951 prediction for the United States of America, the most profound difference is that the world as a whole does not behave as an economically rational marketplace. Something like 75 per cent of all the known oil in the world is in those countries where the control of activities is in the hands of national oil companies. However, only 15 per cent of the wells that get drilled occur in those countries.

Yet more extreme is exploration activity. The last five years have seen 13,000 exploration wells, excluding the United States of America (which would add as many again). Of those, only around 1 per cent were drilled in the Gulf OPEC states. This is not rational economic behaviour. You do not normally focus activities in the places that are less likely to harbour the commodity you want. This is politically motivated, and hence the model that M. King Hubbert applied to the United States – which was entirely economically rational, with activity driven by market forces – does not apply here.

Now, the first trillion barrels of total production has already gone, and if you just took the reserves at their halfway point they would decline tomorrow. But by adding in exploration, reserve growth and unconventional sources, then you have anything up to another 3 trillion barrels. Under this scenario, and

if production were to remain constant at 2005 levels, decline would not set in until we are into the next century. If world demand continues to grow at its current rate, then the onset of decline will not occur before 2020, 2030 or 2040, depending on how much of this oil comes to market. Let's look at the individual components.

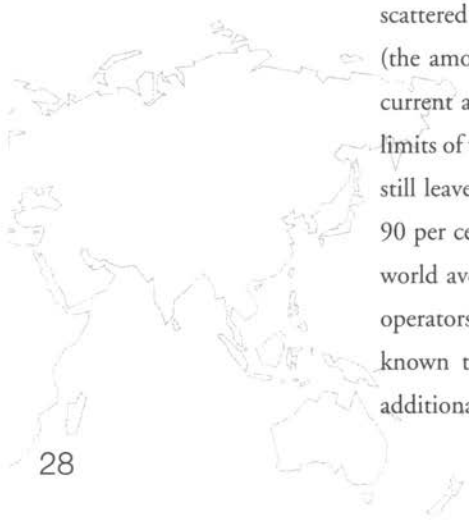
Conventional oil

If you extrapolate the future based on today's track record – with limited access and only a couple of major new provinces and fields – you might expect to find an additional 0.25 trillion barrels of conventional oil. If, however, access opens up over the next decade to where most of the oil in the world actually is, then you might see a very different picture. For instance, there is currently no exploration in Iraq, there is very little in Iran, and there is none in Saudi Arabia. There is also very little in Russia or Venezuela. So the areas where most of the oil is, and that hold the greatest potential for finding more, are in countries where no exploration is happening.

But a world in which access to those countries is not unimaginable – where, if you like, the economic rationality of the oil game can be played effectively – could produce a further 0.75 trillion barrels of conventional oil.

Reserve growth

Reserve growth is difficult to get at, but recent studies at BP suggest that it is actually 2 per cent annually, depending on which measure you are using. As an analogue for the world, BP's widely scattered oil fields are pretty much like other oil fields. Today, BP runs with an average recovery factor (the amount produced as a proportion of the total oil in the ground) of around 45 per cent. With current affordable technology we can take that to 55 per cent. But when you look at the theoretical limits of where future technology and economics could take you, it is an average of 65 per cent – which still leaves 35 per cent behind. This average covers the whole range, from oil fields that will produce 90 per cent plus of all the oil in the ground to those that will only produce 20 per cent. The current world average recovery factor is around 35 per cent, rather lower than the average of people like BP, operators who are essentially driven by economic motivation. But it is not unreasonable to assume that known technology could raise the average recovery factor to 55 per cent. This would bring an additional 1.3 trillion barrels of conventional oil.



Non-conventional oil

There is a lot of future in non-conventional oil. You start with at least 7 trillion barrels in the ground. Remember the world total cumulative consumption to date is 1 trillion barrels. The majority of non-conventional oil (around 66 per cent) is found in countries of economic rationalization such as Canada and the United States. I do not include the current state of Venezuela, with 19 per cent, in that assertion. But most of it is in the western hemisphere and most of it is amenable to the application of current technology.

The application of that technology is already happening. Oil sands growth in Canada, for instance, is set to increase very significantly under today's price scenarios. Depending on people's desire to push for technology, depending on price and on economic rationality, there are somewhere between 0.25 and 1.25 trillion barrels out there.

That takes me back to my first point. The world of today does not behave in an economically rational way, so industry appears to be heading towards a crisis. But the oil is there, so this is predominantly a matter of investment. Without it, a decline in oil is perfectly possible, but a decline is not a fundamental given fact of geology. It is the consequence of politics and hence is amenable to change.

Bernie Bulkin: Jeremy, do you wish to comment on Ian's presentation?

Jeremy Leggett: I agree about investment. This is really where the crisis will play itself out – in countless investment decisions by folk looking to find the giant oil fields that are supposed to be there. But I think that one by one all these little dramas behind closed doors will result in 'no' votes. It is too far away. It is too risky. My prediction, which I firmly hope is wrong, is that not enough 'yes' votes will materialize.

Ian Vann: The element of this debate that I find most difficult to deal with is trying to predict how the world will behave. The underlying geology I am absolutely convinced by, but the decisions that Jeremy is talking about will play out in thousands of scenarios in individual companies, and also, far more importantly, among the decision makers who rule the countries in which most oil and gas actually occurs. It is those decisions that will determine the future. But if decisions continue to be played out as they are today, in circumstances of economic irrationality, for the protection of the state

and in many instances of national companies that are not open to competition (and in many senses not even competent to do the job), then oil supply will get very difficult, and the possible consequences are horrifying.

Q & A

Q: Aren't the Saudis behaving extremely rationally? There is no motivation for them to do exploration now when they can do it at any time in the future. Aren't they being rational in aiming to maximize total income through a combination of price and production?

Ian: From the viewpoint of rationality of an individual producer who can control the market, of course they are behaving rationally. But from the viewpoint of global market rationality this could be mistaken. There is a risk that high prices will ultimately drive new technology away from the internal combustion engine, away from the use of gasoline for transportation. I would also argue that they are driving the world towards a destiny that none of us would like, a destiny that carries the threat of real violence in the world, and therefore is quite irrational in the political sense.

Q: I would like to ask the panel to comment on the Middle East. If I understand correctly, the optimistic projections are that 50 per cent of the new oil will come from that region. But I would have thought that has been pretty well demolished by Matt Simmons' book *Twilight in the Desert*. Do you discredit his analysis?

Ian: I must admit I found it a pretty disappointing book as it had a lot of anecdotes but told me very little. Of course it focused on particular issues in Saudi. If you look around other areas of the Middle East, to the north for example, Iraq has not been explored since the 1950s or 1960s. It has had no significant new technology in the last 25 to 30 years, and it has a national oil company whose leadership tell me that they do not have the competence to do the job they are being asked to do. Iraq today has reserves of the order of 100 to 150 billion barrels, and there is no reason why that figure cannot double. I pick Iraq because it is the most obvious example, but it is by no means unique. Saudi Arabia, on the other hand, has some of the most competent national oil companies in the world. Saudi

Aramco certainly has some of the finest equipment, technology and management. Matt Simmons' book talks about problems with some oil fields, but I am not convinced that those problems will have the result that Matt suggests.

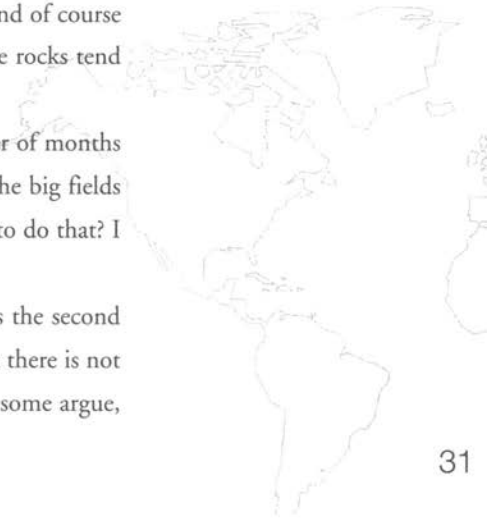
Jeremy: Can I just say that there are anecdotes and then there are anecdotes. In a country where the West has not been able to conduct any sort of verification for more than a quarter of a century, we are almost forced to look at a few anecdotes. Should we not worry about my own anecdote regarding the departed head of exploration and production at Saudi Aramco and his view? We need, and the world expects, Saudi Arabia's production to go from 10 million barrels up through 15 and on to 20 million barrels to keep the whole thing going for a peak of production in the 2020s and 2030s. Yet the gentleman who was in charge of the whole thing said we are never going to get beyond 12 million barrels a day.

Also anecdotally, the last westerner to run Aramco said: 'We have found the elephants, we know where the source rocks are, we know where the big structures are, and they have been drilled. We are not going to find these multi-billion pound quantities in Saudi Arabia.'

The argument goes that we have only drilled X wells in Saudi Arabia where X is a very small number, but we have drilled Y wells in the rest of the world when Y is an enormously high number, and this is supposed to show that we can find more oil if we simply drill more wells. What that ignores is the lesson of so many countries and provinces: you find the big fields first because they tend to be geologically obvious. We have been running seismic tests for many decades, the surface of the planet was fully explored by the 1950s, and every anticline in America was drilled by then. There are not many more places we can go and look. If the oil is there, it has got to be in deep water, and of course we now know that deep-water results tend to be pretty disappointing and that the source rocks tend to be gas prone. I don't get any comfort from this.

I do think the verification point is important. This issue could be resolved in a matter of months if competent teams went in to do the verification. All they would have to do is look at the big fields to see whether the supposedly existing reserves are there. But are we going to be allowed to do that? I don't think so.

The Kuwaiti government has turned around and said that the Burgan field, which is the second biggest in the world, is really ailing. Now there are worries in the Kuwaiti parliament that there is not actually as much as their national oil company are officially telling the world. Therefore, some argue,



they should sit on it, including for domestic use. It is going to be valuable. So I would agree with Ian on this point: it does depend on surface politics rather than subsurface geology. That is another reason for concern of course.

Q: What about the reassessments of reserves in the Middle East? Are they suspect and should we really take out a few hundred billion barrels from the figures?

Ian: When those reserve reassessments were made they looked mightily suspicious since they were all occurring at exactly the same time. However, at the time they were carried out, the ongoing activity of production, the ongoing application of technology, and the growing potential of that technology to produce more were not taken into account. The numbers you find in the Middle East, mainly national estimates of oil and gas, are not very reliable. But when you calibrate them to something you actually know, it seems on average that they are not too bad. This is because while some people exaggerate, others do not see the possibilities that technology can bring. It is pluses and minuses.

Take Kuwait for instance, where the Burgan field is the second or third largest in the world. It's a wonderful oil field, but when water starts to come into the wells it is shut down at only a 5 or 10 per cent water cut (the water cut being the proportion of water to oil in a particular well). In other great oil fields of the world that are operated by national oil companies with today's technology and the investment capability to take care of things, you would run to a 95 or 98 per cent water cut and still get lots of oil. The competence and capability of the operators, and the extent to which nation-states are willing to invest and allow national companies to invest in the resources to increase the potential of those fields, is enormous compared with anything you would do today in the North Sea.

Q: It may be too soon in the discussion to move onto issues of conflation with global warming, but I just wondered if either of you or someone else here could remind us roughly what the number is if you burn a trillion barrels of oil. How much does the temperature of the Earth rise? What is the prediction?

Jeremy: Let's look at how the IPCC (Intergovernmental Panel on Climate Change) is approaching this critical threshold problem. There is general consensus around the view that we dare not go above a 2°C increase in the global temperature. That was set by the European Union as a target as long ago as 1996. It is not clear how scientifically rooted that is, but there is a general feeling that beyond that level the

feedbacks kick in and everything can go really haywire. We dare not go above that level, whatever level of atmospheric carbon dioxide equivalent that entails.

If you look at it in terms of the carbon arithmetic, 400 billion tonnes of carbon would, in the middle range of the estimate, generate enough heat to lock us into that temperature rise. So we must not go above 400 billion tonnes of carbon. Now if the late peakers are right about the trillions of barrels of easily recoverable oil that are out there, and we throw in easily accessible oil from the oil sands of Canada, we have around 700 billion tonnes. Actually it makes no difference if the early peakers are right, because just in oil you are over the 400 billion tonnes. Then you have got the 500 billion in gas and – this is the killer – 3,500 billion tonnes in coal.

Q: To what extent should the petroleum industry be held to account for the climate change threat?

Ian: You have touched on a hobbyhorse of mine. I think we are all accountable in the matter to be honest. We all choose our lifestyles and we all choose to drive our motorcars.

Jeremy: Of course I agree. We are all part of the solution. We all have to bear total responsibility for this. And if we solve the problem it will be because some kind of renaissance enables us to do so. But the idea of common responsibility did not help the tobacco industry, and society is now looking to the company executives for recompense. So if I were a hired consultant to leaders of oil companies I would be counselling extreme caution. It is highly likely that society will look back in anger on all this and do so through the courts. We have already seen what is happening to BP through cost-cutting on health and safety issues around the fire in the Houston refinery. There are going to be real issues and real scrutiny over what has been said in this period, such as statements like 'there is 40 years of supply'. This means you take what we are burning today, project it into the future and then divide it into the proved reserves, which we also have reason to believe are somewhat dubious. I would be counselling against making statements like that, or at least that they be couched in very big caveats, as Chevron and Total are beginning to do.

Q: How successful has solar energy been as a viable alternative to oil?

Jeremy: Solar energy is one of the fastest-growing, most exciting markets in the world, yet it is just a pimple on the backside of this problem. We are still miles away from being able to contribute in

any significant way. But it is a member of a growing family of clean technologies, and given a bit of time and real seriousness of intent it could become very important much more quickly than people think.

Q: If we are going to convert to a low-carbon future, does this mean that much of the oil you are factoring in as consumable will not be available for conventional use because it will be needed for the conversion process?

Ian: I do not stand here as some advocate for the continuation of hydrocarbon use. This was not a debate around demand. This was a debate around whether we should actually focus on the supply side of the problem in a more effective way. I think that some of the worst early peakers live in hope that early peaking will come along and solve the problem. But I believe that people have to solve the problem.

Q: I understand from both speakers that they tend to agree on the geology but worry about where human behaviour might take us. Given that you are talking about Iran, Iraq and Saudi Arabia, to what extent will the political tensions in that region not only get in the way of oil production but also shape the nature of conflicts and governance as oil becomes more of a pressure point?

Jeremy: I think that we are playing a very dangerous game in the Middle East and we are compounding these problems many times through our own response to America's oil supply issues. I commented earlier on the peak in 1970 and the dramatic downturn that followed, leading to the United States of America importing more and more every year. They have shaped up to address this problem in the wrong way. They have not gone the Amory Lovins way. They have not gone the way of energy demand management.

One of the most dramatic statistics in all this is how much Detroit would have to retool in order to obviate the need for all current imports from the Middle East. If people do not know this statistic, it is 2.7 miles per gallon. This is just a slight mpg increase in the shocking average of the American car fleet. That is the road we should be going down. But America has gone the other way, reshaping its armed forces as an 'oil protection force'. That is the terminology that the Pentagon uses, and many of us would question one of those words. This is wrong, and Britain has been wrongheaded in backing it, which is really deepening the problem.

Q: Could you tell us a bit more about the oil sands?

Jeremy: This issue brings us to the conflation with global warming, and it is absolutely essential that we start looking at the carbon implications. You have to burn huge amounts of gas to heat the water to extract the oil. It is incredibly carbon intensive.

I am sure everyone realizes that this is a very different form of oil. You are basically dealing with bitumen, which is solid and very difficult to get at and process. If you look at what the IEA – not known for a lack of optimism regarding what can be done in terms of fossil fuels – are projecting for the future, they say that by 2030 we will be producing the princely amount of 10 million barrels a day.

When you compare this with some of the figures that we have talked about regarding the depletion rate today, when you read the business magazines, you might imagine there is a bonanza, a kind of Klondike, a new Saudi Arabia. But every dollar of investment that is on the table now, if it hits pay dirt, if you will pardon the pun, will by 2015 produce 3 million barrels a day. This is where we are so dysfunctional. Many of the magazine articles on this issue are written by journalists who have no conception of the real problems of depletion or of the difficulties of bringing new capacity online. As a scientific statement there are indeed trillions of barrels of oil – or should I say carbon – in the oil sands and shales. But are they going to become productive? And should we allow them to, given the carbon implications? These are going to be the big issues of the next decade.

Ian: We start with a lot of hydrocarbon underground. It is very difficult to take out and it takes a lot of energy. If you look at the cost of doing that today, probably the best 10 per cent of oil sands will happily produce economically at $35 a barrel, including a notional carbon tax. In economic terms there is a prize there as long as you believe in rates of $50 or $60 dollars in the future.

But Jeremy is also right about it taking an incredible amount of activity, so the biggest problem with the development of Canadian oil sands today is exemplified in Fort McMurray. The town is collapsing under the amount of investment, the inflow of people, the quantity of equipment, a sewage system that cannot cope, a water system that does not work, and so on.

So, slow growth of heavy oil is the most likely scenario. I do not disagree with the numbers Jeremy has been talking about. However, 10 million barrels a day in the 2030s is a little more than 10 per cent of total production, so you are talking real money.

Non-conventional sources are a contribution, not a great white hope, not a new Saudi Arabia, but a

contribution. They will come online because the whole thing is driven by economics and the possibility of access. It is not actually the smartest thing to do but it is the possible thing to do and hence it gets done.

Q: About a decade ago we won the argument to keep Antarctica out of this debate. There are 40 years left to run of the Antarctic Environmental Protocol. Would you like to speculate on the geopolitical pressures to reverse that decision as this scenario plays out? Is there any oil in Antarctica?

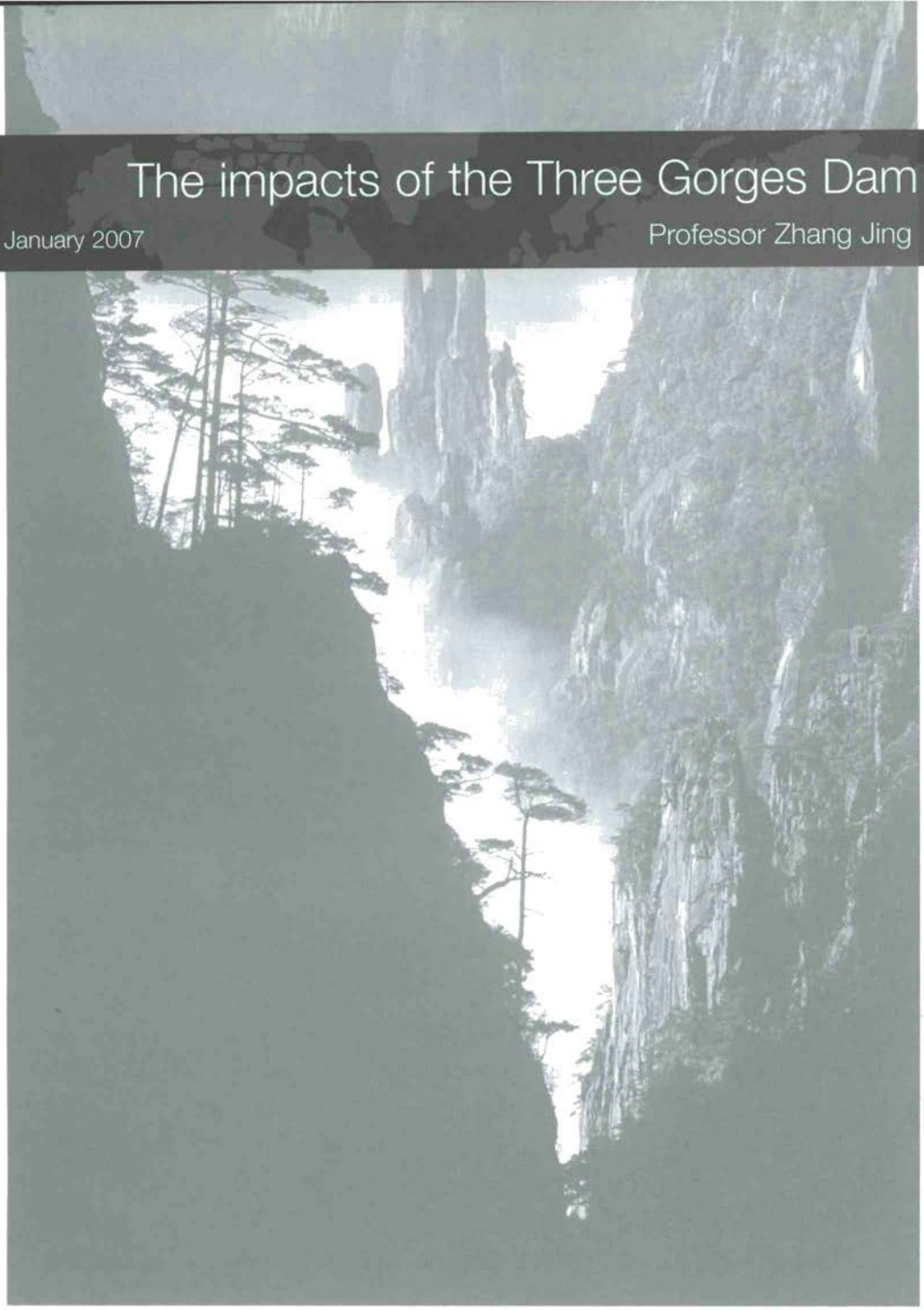
Ian: Of course history usually points to the fact that whether there is oil or not does not matter because the debate is driven by whether or not people want there to be oil. My own view is that Antarctic gas and oil resources are pretty limited and not worth the effort, very different from the Arctic. I am sure there is a huge environmental debate waiting to take place around the Arctic. If the kind of scenario I envisage occurs, the Arctic rim of offshore Russia will necessarily be one of the world's large producers.

Jeremy: My view would be that even if there were megatonnes of oil in Antarctica it would be morally wrong to go and exploit it, especially given the principle of the Antarctic Treaty.

I think I envisage a future of economic dislocation (with a level of 98 per cent confidence in the arguments), and believe we will come through in one of two ways: a free-for-all which has us producing liquids from coal and anything else we can find, never mind about the environment; there will be war and it will be very gruesome. I personally worry about the scope for the rise of fascism on the back of economic dislocation. If that happens Antarctica will undoubtedly end up getting explored comprehensively in a very short time.

The other scenario is where we grasp the opportunity to get it right. We have a massive family of technologies, incredible innovation in low carbon, and that is the route we choose to go down instead of going for far-frontier hydrocarbons and near-frontier coal. These are very fast-moving technologies and we can do it much quicker than people think. We can construct a massive silver lining to the cloud. But I fear that there is little chance of us avoiding a big economic downturn.

Dr Jeremy Leggett, author of *Half Gone* and CEO of Solar Century
Dr Ian Vann, Group Vice-President, Exploration & Production, BP
Moderator: Professor Bernie Bulkin



The impacts of the Three Gorges Dam

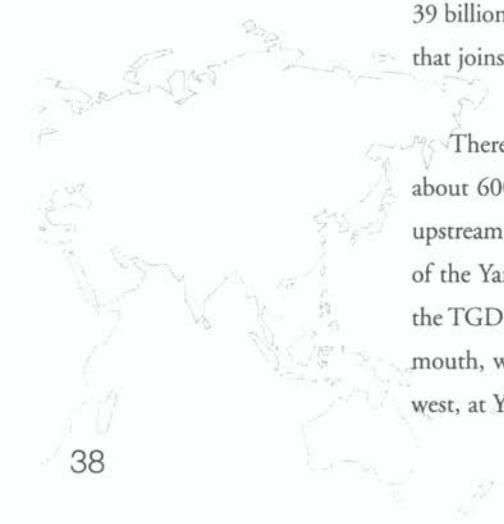
January 2007

Professor Zhang Jing

It is my great pleasure to be here and give a presentation of our research on the effects of the Three Gorges Dam, or Sanxia Dam as it is known in China, on the Yangtze, or Changjiang River. I shall start with an introduction of the number and type of dams we have in China and a broad outline of the Three Gorges Dam (TGD), including its construction and the benefits it has brought, as well as some of the costs. I will follow on with details of three case studies covering the middle reaches of the river, the lower reaches and the coastal environment, and some of the economic and social aspects of dam construction. In the last part of my presentation I shall tell you a little about the post-Three Gorges Dam period, as there are further dams currently under construction or being considered for construction, along with other activities that will have an effect on the Yangtze River as well as the TGD.

The upper reaches of the river that eventually forms the Yangtze are known as the Jinshajiang River, with the Yangtze itself stretching from Nanjing to the coast at Shanghai. The overall river system is more commonly known in China as the Changjiang River. Some 6,000 kilometres long, the Changjiang is Asia's longest river and the world's third longest (after the Nile and the Amazon), and its watersheds cover around 20 per cent of China's land area.

China has constructed more than 50,000 dams in these watersheds over the last 50 years, with a total water capacity of more than 200 cubic kilometres (200 billion cubic metres). The majority are small – under a billion cubic metres – but some are very large indeed. Of the total, around 20 account for more than 50 per cent of overall capacity, and a number of these reservoirs are already at their peak in terms of water storage. Notable amongst these large dams is the Three Gorges Dam, with a capacity of more than 39 billion cubic metres. Another of these very large dams is on the Hanjiang River, one of the tributaries that joins the Changjiang at Wuhan.



There are a few places that I shall refer to repeatedly in my talk. Datong is a large hydropower station about 600 kilometres from the river mouth, the last one on the river due to the tidal effects reaching upstream from the East China Sea. It is a major collection point for data on the water flow and quality of the Yangtze, and it is the changes in flow here that determine adjustments to the discharge rates at the TGD. In the middle reaches of the river is the city of Wuhan, about 1,200 kilometres from the river mouth, with the Hankou station nearby. The Three Gorges Dam lies a further 600 kilometres to the west, at Yichang.

If we put China's dams into a global context, we find that China has more electricity-generating dams than any other country in the world; that Japan has the largest number of dams of more than 100 metres high; and that Brazil has the greatest number of dams with high water-storage capacity. As far as the Three Gorges Dam is concerned, it has the largest electricity generation capacity in the world, generating more than 18 million kilowatts. If you consider the height of the dam, at 181 metres, it is overtaken by several, including the Ertan Dam (also in China) at 240 metres, and the Hoover Dam at 221 metres. And then if you look at its water storage capacity, the TGD has less than a quarter of the capacity of the world's largest – Egypt's Aswan High Dam at almost 170 billion cubic metres.

The Three Gorges Dam has a long development history. A dam was first proposed for the area by the first president of China, Sun Zhong Shan (Sun Yat-sen), around 90 years ago after the Ching Dynasty had come to a close. Then towards the end of the Second World War, the famous American engineer John Lucian Sovage was invited to work in China, and drew up the initial plans for the construction of the TGD. This original 1944-46 design was for a dam of around 200 metres high. Then in 1953 the idea was again raised, this time by Chairman Mao. National Congress gave their approval in 1992 and the whole project got under way in 1994. In 1997 the temporary cofferdams were closed and by 2003 the water level had reached 135 metres, with construction more or less finished. In 2006 the water level had moved up to 156 metres and by 2009, once the construction plain has been flooded, the water level will be up to 175 metres. The whole budget for the project is RMB200 billion (approximately $25 billion).

One of the dam's major benefits is its electricity generation capacity. In line with national evaluation guidelines for environmental protection, it affords a huge carbon dioxide (CO_2) emissions saving from the reduction in fossil-fuel burning, equivalent to about 50 million tonnes per year of coal consumption, representing a reduction of 100 million tonnes of CO_2 and 1 million tonnes of sulphur dioxide.

A further benefit is flood control, reducing the probability of flood from one in every 10 years to one in every 100 years. And another is the facility for increasing the discharge of freshwater from the dam during periods of drought, providing water for irrigation in the middle and lower reaches of the river. In addition, the dam improves fivefold the navigation facility of about 600 kilometres of the middle stretches of the river between Yichang and Chongqing.

In the economic arena, the Three Gorges Dam will offer opportunities for tourism and for new jobs. On the social side, it will alter farming activities owing to improved soil and water conservation, and it will produce new population centres, transforming regional lifestyles from rural to urban.

There are many other advantages. But how we judge the benefits and pay-offs depends on our point of view. So I am also going to talk about the negative effects of the Three Gorges Dam, some of which had not been properly foreseen before construction was complete. There are two contributory factors to this lack of anticipation: one is simply a lack of knowledge, so that the kinds of problems that might arise were simply unrecognized and unevaluated, particularly with regard to sustainable development and the health of ecosystems, and another is that even if certain impacts were foreseen, their seriousness was underrated.

The effects of the dam stretch right across from the watersheds of the Changjiang River system out to the edge of the continental shelf in the East China Sea. The inundated area covers about 650 square kilometres straddling the provinces of Hubei and Chonqing along the middle reaches of the river, and includes a large amount of cultivated land. Local climate has been affected, sediment loads have altered and pollution has given rise to eutrophication. This is a highly ecologically sensitive area, and has become even more so due to both the high water levels and the storage of standing water. There has consequently been a change in the diversity of the region, including the loss of endangered species such as the river dolphin. As the river has become a lake, there have been shifts at all levels of the ecosystem, from low plankton to phytoplankton through to fisheries, and so on through the food chain.

In terms of biological diversity, the TGD region is home to 120 different families, 360 genera, and 560 species, including the Chinese sturgeon, which is now highly endangered as a result of the dam construction. Some are so special that we do not even have English names for them, for example *Myricaria laxiflora*, a riverside plant endemic to the Yangtze. In addition, the migration patterns of certain fish species have been disrupted.

Another issue surrounding the dam is the huge human population that had to be moved. The whole reservoir is about 600 kilometres in length, affecting five different cities and provinces with around 20 local communities in the area of inundation. Some 1.2 to 1.4 million people in total have been moved, with farmers making up around 40 per cent of that figure. About 20 per cent have been relocated to the

coastal region where economies are better developed but, even so, human population movements of this size inevitably lead to cultural clashes and conflicts over resources.

The area under inundation is rich in history, and some 1,100 sites have either been lost or have required some form of protection. These historical sites go back around 3,000 years. In addition, there are hydrographic records of the region that go back 1,400 years.

Another problem associated with the dam is landslides in this geologically sensitive area. Examples include one at Yunyang/Chingqing in 1982, which shifted 15 million cubic metres of soil and rock, one in Zigui/Hubei in 1985 (13 million cubic metres) and another one in Yunyang/Chingqing in 2001 (50 million cubic metres). Large quantities of this soil and rock have moved directly into the river, blocking it to some extent.

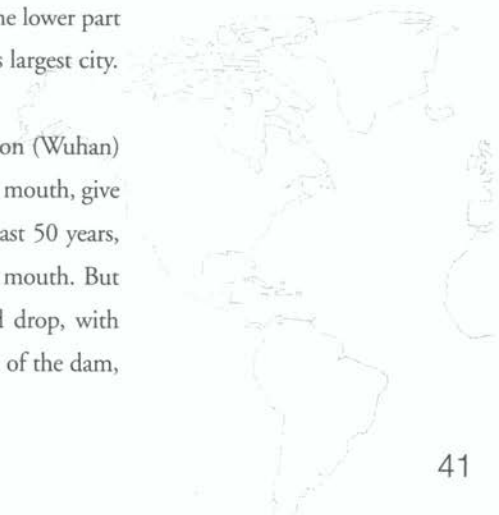
So that is the overview of both the good side and the bad. And while we must enjoy the benefits of the huge amount of electricity generation, flood protection and drought alleviation that the TGD has afforded, we must also bear in mind the negative consequences, both unforeseen and under evaluated.

Case studies

Case study 1: From the middle reaches to the Yangtze delta

We have to ask ourselves how well we anticipated changes in water flow and sediment loads resulting from the dam and how these might affect the stability of the delta region, as well as the risks of eutrophication in the reservoir and a resulting deterioration in the aquatic environment and water quality. The lower part of the Yangtze River is a heavy navigation channel with a busy harbour at Shanghai, China's largest city.

Data taken every decade from the Yichang station just below the dam, the Hankou station (Wuhan) 1,200 kilometres from the river mouth, and the Datong station 600 kilometres from the river mouth, give us an idea of the changes. As the number of dams in the watershed has increased over the last 50 years, there has been a series of drops in sediment load recorded between the TGD and the river mouth. But when the TGD came into operation in 2003, there was a much larger and unanticipated drop, with sediment loads 50 per cent lower than expected. This has negative consequences downstream of the dam, particularly in the estuary.



With regard to chemical loads in the Changjiang following closure of the TGD, phosphate loads increased considerably immediately downstream of the dam, decreasing a little nearer to the estuary. Silicate levels also increased following closure of the dam, though these appear to have dropped according to a 2006 study. Nitrate concentrations, which increased in the vicinity of the dam following its closure, are now heavier closer to the estuary. Observational data for dissolved organic carbon, particulate organic carbon and dissolved inorganic carbon remained fairly stable between 1997 and 2003. Samples collected in a more recent study are currently being analysed and the data should be available soon.

Eutrophication resulting in algal blooms is a common problem around the tributaries in the dam region and in the reservoir, with a considerable effect on aquatic systems and biodiversity. All the tributaries discharging directly into the reservoir have five- to tenfold higher nutrient loads than the mainstream, as well as higher levels of chlorophyll (resulting from purification processes) and biomass. Of course the application of fertilizer in the watersheds has also increased over the last few decades, in part contributing to the greater flow of nutrients both into the reservoir and to the East China Sea.

After the dam closure in 2003, seasonal variations in the delta could still be seen, but overall the elevation of the coastal wetlands has decreased rapidly. Although sediment loads from the tributaries have increased a little, and erosion of the riverbed has also contributed to the sediment load, there has overall been a fourfold drop in sediments reaching the estuary and a corresponding drop in accretion rates. Erosion has deepened the channels in some places, and the delta front as a whole is moving landwards. This decrease in sedimentation of the estuary is of particular concern because of its effect on the local fauna. Polychaetes, molluscs and crustaceans have all decreased considerably, with a dramatic drop in total species numbers. Traditionally, the Yangtze River Delta is a spawning and fishing ground for important economic species such as the Chinese mitten crab and the grenadier anchovy, as well as a migration route for these species. But the change in the sediment load and the reshaping of the delta region due to human activities has had a major effect: some of the spawning grounds have been totally destroyed.

In summary, our most important findings have been that the response of the delta region to dam construction has been very rapid even though the dam is 2,000 kilometres upstream. The significance

of this kind of response is not only in the decrease of the amount of sediment flowing to the delta, but also the changing shape of the delta itself.

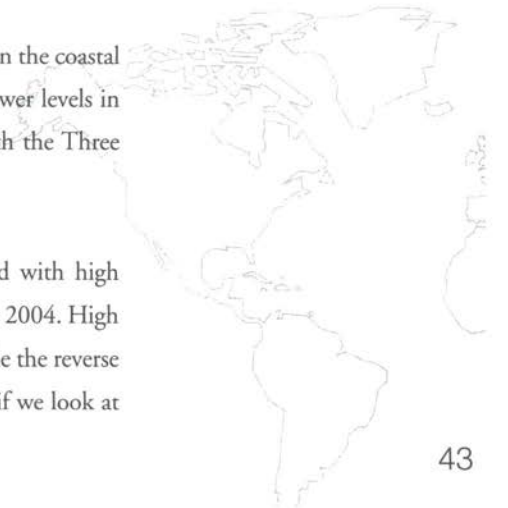
Case study 2: The coastal region and the East China Sea

Our second study has been on changes in the quality of the coastal waters, including eutrophication and hypoxia, nutrients and trace elements, and changes to the habitat and food web that affect the broader ecosystem. Historically, the Yangzte River discharges a huge amount of freshwater to the East China Sea. In the flood season when the river is in full spate, the freshwater outflow can reach as far as the continental shelf break, several hundred kilometres from land. The coastal region is also an important spawning and hatching ground for commercial fish species that spend their early stages in the coastal areas and then move to the deeper waters in the outer part of the shelf region. So any changes in terms of water and sediment load may also cause problems between neighbouring countries in the area that have claims on the region's marine resources.

Some of you may not be familiar with the circulation pattern of the East China Sea. In summer the Changjiang waters move eastward, joining with the Taiwan current from the south and affected by the very powerful Kuroshi current that moves northwards at the outer edge of the East China Sea. In the winter under the monsoon effect, most of the water coming off the Yangzte River moves southwards along the coast towards Taiwan. The influence of the river can be tracked several hundred kilometres from the river mouth, with heavy nutrient levels in the coastal waters leading to eutrophication problems when temperatures are high.

A study comparing nutrient loads and phytoplankton biomass in 1998, 2003 and 2004 in the coastal waters at the Yangtze River mouth, undertaken by colleagues in Taiwan, in fact recorded lower levels in 2003-04 than in 1998. And we are right to wonder whether this change is connected with the Three Gorges Dam. But of course there is no simple answer.

There were relatively low levels of salinity in these waters in 1998, usually associated with high freshwater discharge rates, and these were in fact 40 per cent higher in 1998 than they were in 2004. High discharge rates were accompanied by low salinity levels and high nutrient loads in 1998, while the reverse was true in 2003-04. But we must not assume that this had anything to do with the dam: if we look at



water discharge rates measured at the Datong station during the period 2001 to 2005, covering the time when the dam came into use, we see no significant change in water flow. Nutrient loads in the coastal waters may have dropped between 1998 and 2004, but phosphate and nitrate loads recorded at Datong actually rose slightly over the period 1998 to 2005, while other nutrients and silica remained more or less stable. And there are other factors to take into account. Estimates suggest that nutrient concentrations both in the Kuroshi current and in the Taiwan current, which carries street runoff, are higher than in the Yangtze discharge waters. The Yangzte accounts for as much as 95 per cent of the whole river discharge into the East China Sea. Nonetheless, the effect of Changjiang's waters on the biochemistry of the East China Sea may be overestimated owing to lack of data for all the elements that impact the marine waters.

That said, the chemical loads in the Yangtze River outflow do have an influence on the coastal environment. Nutrient levels in the East China Sea are very considerably higher close to the coast, where we have seen an increase in the number of harmful algal blooms in the surface waters. Deeper in the water column, at depths of 20 to 50 metres, a large area just off the Yangtze River mouth is very low in oxygen, with levels of only 1 or 2 milligrams per litre. But it is difficult to make any direct link between this hypoxic zone and the Three Gorges Dam because the decrease in oxygen levels in the near-bottom waters has in fact been roughly linear over the last 50 years.

If we are to get a true picture of the effect of the Three Gorges Dam on the highly sensitive ecosystems of the coastal region, monitoring and research must take place at the basinwide level over several decades. That is something we are doing in China right now.

Case study 3: Social and economic aspects

Building a dam is initially an engineering issue, but it is also where problems of science, politics, society and engineering come together – and with profound impacts. Our third case study has looked into the social and economic effects of the TGD.

Migration associated with the dam has taken place over the last 10 years, and has involved the involuntary resettlement of between 1.2 and 1.4 million people to 11 different provinces and cities. The government's resettlement expenditure has been RMB40 billion (approximately $5 billion), about one fifth of the total budget for the dam construction.

The inundated area behind the dam covers around 650 square kilometres and has involved the loss of some 24,000 hectares of cultivated land as well as some 1,600 companies and factories. The majority of the affected population has moved eastwards, with around 20 per cent to coastal areas, including about 5,000 people to Shanghai, 8,000 to Guangdong and around 10,000 to Jiangxi.

In theory this could be a good thing, because people from the TGD region are having an opportunity for a new life by moving from a less-developed region to a well-developed one. But there are several problems that were not properly considered prior to the construction of the dam. For example, little consideration was given to people's ability to abandon their traditional lifestyle and adapt to a new one, losing, in the process, their community and family networks, and their properties and farmlands. They are having to learn new forms of cultivation requiring different farming skills, moving from the drier regions of Chongqing where maize and some fruits predominate, to a humid area where rice is the dominant crop. So while on the one hand there is an opportunity for improved economic well-being, there are difficulties of adaptation on the other, as well as competition with the existing communities for natural resources.

The social and economic consequences of TGD resettlement take place at a variety of different levels, some of which go unnoticed. At a national level the resettlement programme is managed according to national legislation under Congress; at the local level it is managed in a different way by the local governments; and at an individual level it is managed differently again according to cultural traditions, lifestyles and mentalities that can be quite alien to the new environment. All this can sometimes cause very serious conflicts between newcomers and existing communities.

Older people and young children have particular difficulties in adapting to a new life. For example, in most of the coastal region, even though Mandarin is the official language in high schools and primary schools, there are very strong regional accents. So newcomers to the coast have problems understanding and being understood, the children struggle to keep up in class, and communication between teachers and parents is awkward.

On the whole, young adults find it easier to adapt as they usually have better opportunities to find a job, but even then, retraining and reemployment have not been taken sufficiently seriously. This has been exacerbated by bureaucracy at the level of local government and even by problems of corruption.

And then there is the issue already touched upon of the loss of historical sites. All of these factors have been painful for our country: cultural change; resource competition; cultural conflict; interrupted education and the loss of sites of historical significance.

Looking ahead

The story of the TGD is far from over. A great deal of activity is going on in the Yangtze River area during what I call the post-TGD period. Further dam construction and other human activities are continuing in the watersheds, all of which will affect the functioning of the TGD and make the story yet more complex. Four other major dams are either planned (Wudongde and Baihetan) or already under construction (Luoxidu and Xiangjiaba) upstream of the TGD towards the Jinshajiang River. Together, they will have even higher electricity generation and a larger water-storage capacity than the Three Gorges. This will have a considerable effect, given that the Jinshajiang supplies around 16 per cent of Changjiang's water flow and almost 60 per cent of its sediment load.

The flow of the Yangtze will also be affected by water extraction to supply the north of the country. Government plans, approved by National Congress, are to build canals from the upper stream of the Yangzte River to the upper stream of the Yellow River; from one of the big tributaries at Hanjiang in the middle reaches up to the north; and from the lower reaches via the 'Grand Canal' to Beijing and Tianjin. Between them they will have an average water transport capacity of 2,000 cubic metres per second. The main question is how these 2,000 cubic metres per second will be managed seasonally. If this water is moved in the flood season it will be manageable, but if it is moved during the Yangtze's dry season it will cause new problems.

Finally, beyond all this immediate human activity, there is the question of climate change. The Datong station recorded exceptionally low water flow in 2006, more than 30 per cent lower at peak flow than had been recorded for the years 1996 to 2005. At the beginning of this lecture I said that the TGD discharge rate is regulated according to changes in flow at the Datong station, so that if flow at Datong becomes very low, more water is released from the TGD. On the whole this has worked well, but nationwide drought in 2006 was beyond the capacity of the TGD to correct. This situation could become very serious indeed, as the effects of a river running dry can be as catastrophic as flood, with major impacts on an important navigational waterway as well as on local needs for irrigation and water supply.

So all these ongoing activities, coupled with the unknown impact of climate change, make it very difficult to isolate and analyse the impacts on the wider water system and coastal waters of the Three Gorges Dam itself. It is a very complex scenario. The only thing that we are quite sure about is that the reduction of sediment in Yangtze waters downstream of the dam has been much greater and more serious than was anticipated. But any conclusive analysis of environmental and marine impacts will require data gathering and monitoring over decades, as the life cycles of affected species, including commercial ones, can take place over several years. With regard to the socioeconomic effects of the dam, analysis would have to be carried out at the national level for it to be truly meaningful.

So taking all this information together, and sediment loads aside, the only conclusion I can draw is that any so-called conclusions would at this point be premature.

I would like to thank the University of Cambridge for the invitation to give this lecture, and also the research team and colleagues who have worked with me to prepare it.

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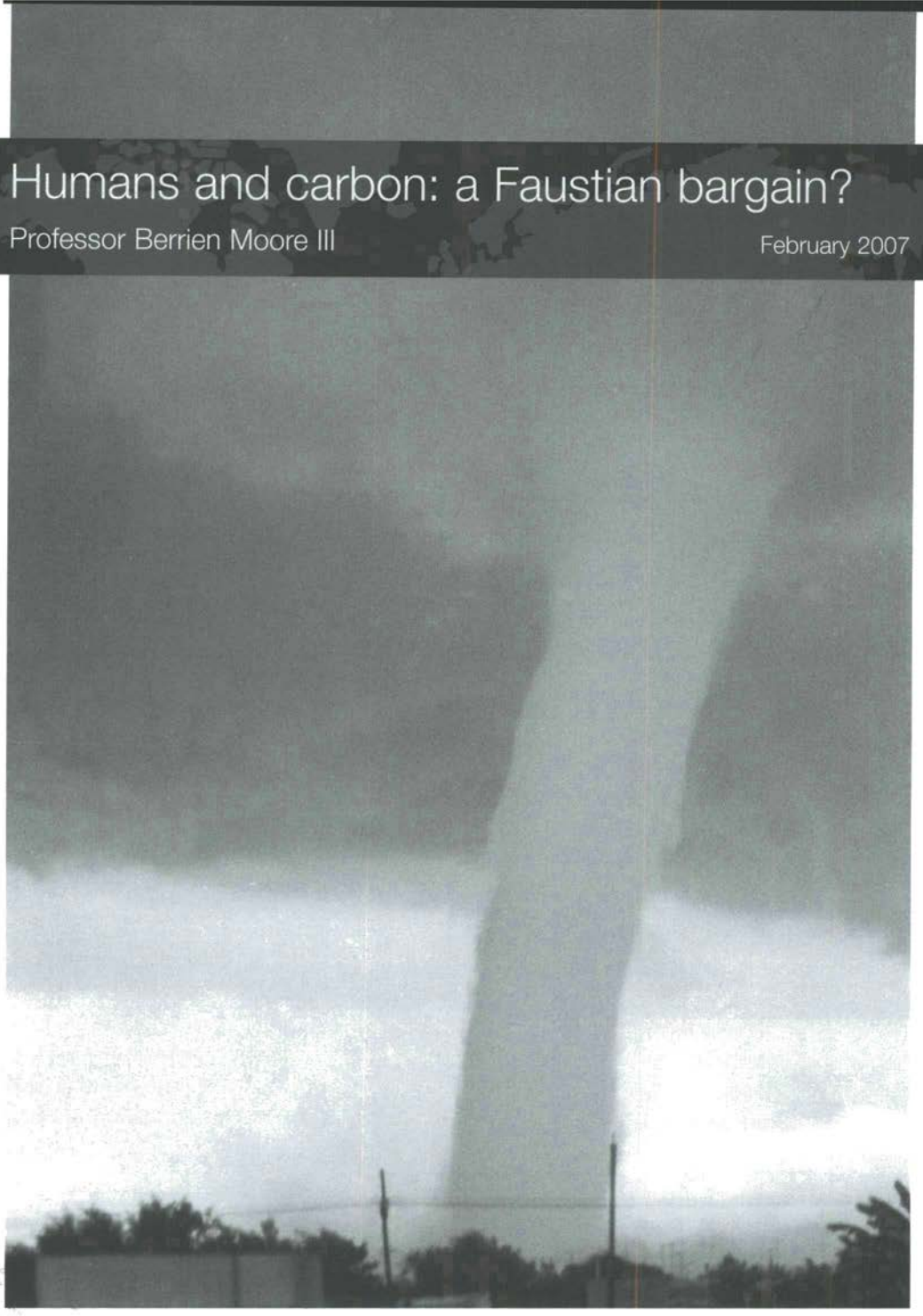
Humans and carbon: a Faustian bargain?

Professor Berrien Moore III

February 2007



I am going to talk about the carbon cycle and the CO_2 problem. I have used in the title of my lecture the phrase 'a Faustian bargain', and hope that the rationale behind my choice of words will become clear as we go along. Carbon is the fundamental material in the cycle of life on our planet. The Bible refers to it as 'dust to dust' – the formation and decomposition of organic material. Some of that decomposition has left us with a lot of stored carbon in the form of fossil fuels, and we are taking it out of storage much faster than nature had in mind.

One way to think of the carbon problem is in terms of economies or inflation. By burning fossil fuels we are in a sense printing carbon money; we are taking this carbon money from bank accounts where it has been out of circulation and reintroducing it into the system. The carbon that was sequestered, or removed from the system, is now reentering the cycle and effectively inflating it. This, in itself, would be important because it is a significant change in the fundamental chemical cycle of the planet, but as is well known, the change is magnified because increases in CO_2 lead to an increase in the trapping of heat in the Earth's atmosphere, which alters the net energy balance of the planet. Even a slight change in the balance between energy entering the atmosphere and energy leaving the planet potentially affects the climate.

Here are a few numbers. In the 1990s, through the burning of fossil fuels, we were adding about 5.5 gigatonnes – or billion tonnes – of carbon to the atmosphere as CO_2 annually. And in the mid-1990s there were about 5 billion people on the planet, so around a tonne of carbon per person per year was being produced as CO_2, primarily through fossil-fuel burning and cement production. Of course deforestation also produces CO_2, but the difference between burning a tree and burning oil is that the tree might recover or be replaced, allowing the carbon to flow back into vegetation.

Of course a great deal of carbon goes back and forth in gross fluxes. Around 90 gigatonnes annually flow between the ocean and the atmosphere, with slightly more (about 2 gigatonnes) entering the ocean than leaving it. This net inward migration occurs because as you put more CO_2 into the atmosphere, the partial pressure difference forces it into the ocean.

The carbon exchange with the biosphere is about 120 gigatonnes. Of the 120 gigatonnes that are fixed by vegetation through photosynthesis, 60 gigatonnes integrated over the year are respired back from vegetation during the nighttime, and the remaining 60 gigatonnes go back over a longer period of

time from the litter and soils. Overall, there is very little net change to the stored carbon in living vegetation of around 610 gigatonnes. The atmosphere holds around 750 gigatonnes of carbon, more than living vegetation, but so dispersed that it is measured as a trace gas in parts per million (ppm).

Some remarkable data was gathered by Charles David Keeling, who started measuring atmospheric CO_2 in 1957 at Mauna Loa, the second highest mountain in Hawaii. He took his measurements daily at about 3,350 metres in very clean air away from the active summit.

Initially, it looked as if CO_2 was rising absurdly fast, but of course what was happening was the annual cycle. Measurements began in the fall of the year when respiration dominates photosynthesis; this was what was being observed. By spring the growth slows and turns down as organic matter is being formed; in fact CO_2 is drawn down throughout the growing season, and then released back into the atmosphere when the material is oxidized in the autumn. An enormous planetary metabolic cycle takes place, with atmospheric concentrations rising and then falling again by around 5 ppm annually. But on top of this natural annual flux, Keeling's measurements recorded a near continuous rise of atmospheric CO_2 of about 60 ppm over the second half of the 20th century and into the 21st, reflecting our industrial activity.

If we look back over the last 1,000 years by examining the Law Dome ice core records, here too we can see evidence of the Industrial Revolution taking place. Of course there were modest fluctuations in CO_2 concentrations prior to the 1800s, of the order of 10 ppm, but since the middle of the 19th century the trend has only been up. And as we have moved into the modern era and taken atmospheric rather than ice core measurements, the curve has only steepened. An interesting point is that about half the CO_2 released during the industrial era – through fossil-fuel burning and cement production – occurred prior to 1974, and about half since that time.

If we go back further in time, temperature records for the last 400,000 years from the Vostok ice core in Antarctica show us the patterns of the last four glaciations, with temperatures varying by 10°C between the glacial and interglacial periods. It is an extremely rhythmical pattern: temperatures fall in steps, and then rise in one comparatively gigantic leap, only to repeat the pattern. If we compare these fluctuations with CO_2 concentrations, we find them in lockstep. Each glaciation consistently gives us an atmospheric CO_2 concentration of around 190 ppm at peak glaciation, while each interglacial period

has an atmospheric CO_2 concentration of around 285 ppm. It's a perfectly coordinated dance routine with CO_2 reinforcing the orbitally induced climate changes.

But let's look again at current concentrations. At 380 ppm these are far above anything that has occurred over the last 400,000 years, so even if we weren't concerned with greenhouse gases and our climate, we would know that something unusual is happening to the global carbon cycle. And, according to the Intergovernmental Panel on Climate Change (IPCC), we are heading towards concentrations of more than 650 ppm by the end of the century, far more than double the historical interglacial levels.

As I mentioned earlier, in the 1990s we were producing around a tonne – perhaps a little more – of carbon per person per year on average. Of course not all people emit the same amount. The average US citizen accounts for nearly 6 tonnes per year (up from around 4.5 in 1950), while the average Chinese citizen accounts for around 0.75 tonnes (up from about 0.04 in 1950). On a per capita basis, China is still below the world average, though as a country it is on the brink of overtaking the United States as the world's greatest emitter.

Let us go back to the climate system for a moment, because that is of course the central issue with CO_2. The energy that reaches our planet is partitioned in many different ways. Some of it bounces right back out again because it is reflected by clouds or ice. Some is turned into thermal energy and escapes back to space. Some is absorbed and stored. But by adding CO_2 to the atmosphere we are changing ever so slightly the net energy balance and this is now beginning to change the climate.

Let us reflect upon the last two IPCC Assessments. From the Third Assessment Report of the IPCC: 'There is an increasing body of knowledge of climatic and other changes in physical and ecological systems that points to a warming world. Global surface temperatures have increased by more than half a degree since the beginning of the 20th century, and there is ever stronger evidence that most of the warming observed over the last 50 years can be attributed to human activities.'

By 2007, the picture was more certain. The IPCC's Fourth Assessment Report states that the warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea

level. It is warmer now than during the last 1,300 years, and the last time the polar regions were significantly warmer than at present for an extended period (about 125,000 years ago), reductions in the volume of polar ice led to a sea-level rise of 4 to 6 metres.

For the next two decades, an increase in the average global temperature of about 0.2°C per decade is predicted. And even if we levelled off the atmospheric increase of CO_2, temperatures would still continue to go up by about 0.1°C per decade as the planet comes into a new equilibrium. Climate response will lag behind the CO_2 force, and this is what needs to be thought about right now. This is the key statement: anthropogenic warming and sea-level rise will continue for centuries even if atmospheric greenhouse gas concentrations were to be stabilized immediately.

In the Third Assessment, using various IPCC scenarios and models, we see that global temperatures are expected to rise by between 1.4 and 5.8°C over the next century. There is a great deal of uncertainty, hence the wide range of outcomes. About half of this is due to the variety of energy policies we could pursue. The other half reflects scientific uncertainty about climate change *per se* because of various feedback loops and the difficulty in predicting their effects.

In the Fourth Assessment, the range of models now available suggests a strong climate-carbon cycle feedback – as the climate system warms, higher levels of CO_2 will be released into the atmosphere. This tends to shift the expected temperature range to the high end of the Third Assessment. But the magnitude of this feedback is uncertain, increasing the uncertainty in the trajectory of CO_2 emissions required to achieve a particular stabilization level of atmospheric CO_2 concentration.

I would now like to return to the carbon cycle.

First and foremost, if you put more CO_2 into the atmosphere, more goes into the ocean because it is exchanging differences in partial pressure. Beyond this, the amount of CO_2 in the sea surface is affected by many things, two of which are particularly significant: first is biological activity, where phytoplankton in the surface waters take up CO_2 and move it down through the water column in a 'rain' of 'dead' organic matter, providing a storage route to deep ocean abysses; and second is the large-scale circulation of the ocean.

The reason you have springtime in England well before we have it in New England – even though England is on a much higher latitude – is because of the western boundary current of the North Atlantic. The American continent (and the rotation of the planet) effectively induces a circulation northwards – the Gulf Stream – that delivers heat to Europe.

As this water moves to high latitudes, it gets both colder and saltier, because as ice forms it leaves salt behind. In addition, evaporation exceeds precipitation in the North Atlantic, making it even saltier, eventually producing dense surface water that leads to convective overturning, and the water goes down. The solubility of CO_2 also increases as the temperature drops, so as the water gets cold it takes up more CO_2, and then that CO_2-rich water sinks down to deep areas. The macrocirculation of the ocean, along with phytoplankton, is what allows the ocean to take up a significant amount of CO_2.

In a warming world of course the surface ocean will get warmer and so solubility will decrease. The ocean may also stratify, with reduced nutrient upwelling, turning down the rate at which biota is formed. So many of the feedback loops suggested by a climate-warming scenario lead to oceans taking up less CO_2.

Let me move back onto dry land. Of the 120 gigatonnes of carbon that are taken up by vegetation annually, remember that about 60 gigatonnes go right back to the atmosphere during nighttime respiration and about 60 come out slowly later. Some of the carbon is disturbed through forest fires and so forth and immediately released, and maybe a small amount of 1 or 2 gigatonnes might end up in long-term storage.

Now all these numbers were put together in the 1980s, when we needed measurements of the carbon cycle in order to get to grips with the influence that fossil-fuel burning might be having. But it is a very tough set of numbers to get. What do you measure? How do you scale this up? How much is going into the ocean? How much is being released by deforestation? Only about half of the CO_2 produced through fossil-fuel burning was showing up in the atmosphere, so what was happening to the rest?

We needed to add up these numbers and work out how much carbon was coming in and how much was going out. But by the 1990s we simply said 'we don't know, we are not even going to write a number down because we don't know how to get at that number'. Clearly it was important.

The rising curve made by Keeling's measurements had become as familiar to us as the face of the Mona Lisa; you didn't even need an axis to know what you were looking at. But we still couldn't do the sums.

Keeling's son, Ralph, a scientist at Scripps Institution of Oceanography, continued with his father's CO_2 records, but added a new dimension to the equation. He began to measure changes in the oxygen concentration in the atmosphere. This is no trivial measurement: oxygen makes up 20 per cent of the atmosphere, and changes are very, very small – insignificant as far as we are concerned. But they reveal much about carbon sinks.

As carbon burns it uses oxygen, and with knowledge of the carbon-oxygen ratio of burning fossil fuels, you would expect a certain increase in CO_2 alongside a certain (very small) decline in oxygen. At the same time, it was known that there is no oxygen involved in the process by which the ocean absorbs CO_2 (simple acidic dissolution in the water), but that oxygen is produced in the process by which vegetation takes up CO_2. So by measuring the actual decline in oxygen and comparing it to the decline you would expect from our rate of fossil-fuel burning, Ralph was able to work out where the 'missing' CO_2 was going. He was able to differentiate how much CO_2 was going into the ocean, and how much into the land. A brilliant piece of data; absolutely remarkable.

The other remarkable record is Roger Francey's data from Australia. He looked more closely at the Keeling CO_2 record and observed that, while CO_2 concentrations are on the rise overall, the annual rate of change – and I'm not talking about the annual biological cycle here – varies significantly. Yet the rate of increase in burning fossil fuels is fairly constant, too constant to account for the variability in the CO_2 increase rates. In fact in some years it looks as if all of the excess CO_2 stays in the atmosphere, while in others none of it does. There are obviously other important processes going on.

What are these sources of CO_2 other than fossil fuels, and what are the sinks? This is a really important question.

The issue of unresolved sinks is particularly worrisome. For instance, many mathematical models have been constructed to establish long-term scenarios of anthropogenic CO_2 emissions and the measures that

need to be taken to stabilize CO_2 at given levels over a given time frame. But it is easy to draw the wrong conclusions. High levels of CO_2 have a fertilization effect (actually making plants more water efficient), increasing the land's biomass. So the idea emerged that more CO_2 meant more land biomass, which meant more carbon storage, so that as long as you eliminated deforestation, the expanding biomass would balance out CO_2 emissions. The mistake was in concluding that this could go on *ad infinitum*. It appeared to suggest that as long as we kept expanding land biomass, we could just keep on increasing our emissions of greenhouse gases. An absolutely crazy idea the more you look at it. But the source-sink balance remains critically important with regard to what will happen in the future.

How can we get at that question? Well, one way is to go around and measure everything from the grassroots level, from the bottom up, starting with terrestrial systems. We put up tall towers to measure over the tops of forest canopies. We fly around in aeroplanes to monitor what is happening over landscapes. We make biomass inventories and study ecosystems. Or we go to sea in oceanographic vessels, we study VOS (volunteer observing ship) lines, mooring time series and ocean processes, and we use satellite data to study ocean physics. And then we can create mathematical models. But this is a very 'bottom-up' way to try to constrain the problem, and there is a lot of noise and uncertainty. I don't think this is the way to do it.

I think we are going to need to monitor CO_2 from space. CO_2 is chemically uninteresting in the atmosphere – it does not actually do anything; it is conserved. So if you measure minute changes in the concentration of CO_2 at many points around the planet, you could begin to plot exactly where it is coming from and where it is ending up. NASA's Orbiting Carbon Observatory (OCO), to be launched in 2009, will do just that.

However, the OCO is probably not going to deliver as much as we would like because it cannot gather data on atmospheric CO_2 at all times. It needs to measure the wavelengths of sunlight reflected back from the planet in order to detect CO_2, so can only measure CO_2 while photosynthesis is occurring, not during nighttime respiration. We cannot measure CO_2 in high latitudes during the winter. Perhaps the answer is to provide our own 'sunlight' by using a laser, firing it down to Earth from the Observatory and then measuring what comes back. Of course we would still need all the more grassroots methods of data gathering too, but by getting a global picture we might begin to constrain the problem.

Let me just change the topic a little and go back to the climate system. Now I want to begin to build the case for the 'Faustian bargain'. I am going to take just one piece of the climate system: Arctic sea ice. There is increasing evidence that there is a decline in the extent and thickness of Arctic ice, particularly in the summer. Satellite data since 1978 show that we are losing sea ice at about 3 per cent per decade, with larger decreases in the summer of maybe 7.5 per cent per decade. Why is that important? Arctic sea ice is white, highly reflective: turn the sea dark and you change the reflectivity – the albedo – of the planet. That changes the energy balance in exactly the wrong way: an increase in surface temperatures leads to a decrease in sea ice, which leads to a decrease in albedo, which in turn leads to an increase in temperatures.

It may be that there is some other feedback mechanism out there that could have the opposite effect – perhaps increased evaporation from an ice-free Arctic Sea would replace the albedo of ice with the albedo of clouds. There are lots of different feedbacks, but this one is right at the core of the problem and we simply don't know enough about it. And there is something else going on in the Arctic that worries me. If you start to decrease Arctic sea ice you will freshen the Northern Atlantic, which may affect the turnover current that warms northern Europe. If the ice is 'unforming', the water will become less salty and less dense, changing this major circulation of the ocean. According to the IPCC's Fourth Assessment Report, 'it is very likely that the meridional overturning circulation (MOC) of the Atlantic Ocean will slow down during the 21st century'. And it goes on to mention a reduction of anything from 0 to 50 per cent. However, it also says: 'It is very unlikely that the MOC will undergo a large abrupt transition during the 21st century.' But a 50 per cent reduction seems a pretty large one – I'm not sure exactly what's going on here, but this really needs to be thought about further.

So now we come to the bargain. We seem to have made an agreement with our industrial selves, yet we also seem to think that we can get out of this agreement whenever we want to. So we'll continue to burn fossil fuels until we see something bad happening – for ourselves, our society or the world – and only then will we try to back out. But we can't. The climate is a dynamic system, and we have inflated the carbon dimension of that system by adding carbon that simply wasn't there. If we manage to stabilize emissions at 2000 levels, atmospheric CO_2 concentrations will continue to increase and temperatures will continue to rise at 0.1°C per decade. So it's not just our CO_2 emissions that need to be stabilized, it's the whole atmosphere, and this would require drastic reductions in emissions.

But this is where the real Faustian bargain comes in. The climate system is a dynamic system and changes in the composition of the atmosphere are an initial forcing mechanism for a set of ongoing climatic changes. We have kicked a ball off a hill, and now it is just rolling on down. Changes in Arctic sea ice and therefore the reflectivity of the planet no longer have anything to do with CO_2; the system was set in motion by changes in atmospheric CO_2 concentrations, but now other changes (e.g., Artic sea ice) begin to exert their influence. Even if we managed to stabilize not just our emissions, but the whole of the atmosphere, these changes will continue to take place. There is a precommitted climate change.

And if we carry on increasing our emissions, then reductions in CO_2 will have to be even more drastic – maybe to just a quarter of what they were in 2000. Even then, we can expect atmospheric and temperature stabilization to take several hundred years, sea-level rise through thermal expansion to continue for many centuries, and sea-level rise from melting ice to go on for several millennia.

Our part of the bargain is far more than we bargained for. This would not be so difficult if we were concerned with something like the ozone hole. There too, we kicked something off with our CFCs and our fluorocarbons, and sorting it out was difficult enough. But there is a huge difference. Fluorocarbons are on the edge of the economy and the environmental impact was limited to the high elevation of the atmosphere in the springtime in Antarctica. This was very important, but CO_2 is right at the core of the global economy, and climate change is not just over Antarctica; it's right over the planet.

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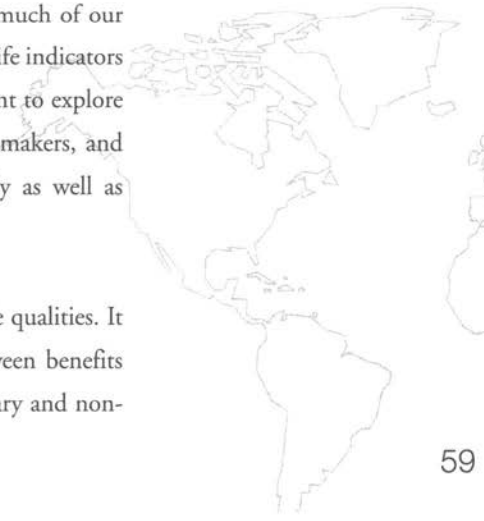
Valuing sustainability

Richard Saxon CBE

March 2007

Sustainability is the greatest challenge faced by our civilization, in that, as other speakers in this distinguished series have said, and as Sir Nicholas Stern's report demonstrated, our current trajectory cannot be indefinitely sustained, economically, environmentally or socially. The transition to a sustainable path is however beset by barriers, of which the most entrenched is the perception that long-term environmental sustainability, the most urgent issue, is not achievable without short-term economic loss and politically unacceptable lifestyle change. Whilst the triple-bottom-line concept of sustainability implies that economic and social sustainability cannot exist without environmental sustainability, the reverse is also true. We cannot hope to achieve a sustainable environment unless we can afford it, through continuing economic success and increasing social equity across the planet. This suggests a concentration on seeking low-cost techniques to reduce emissions and on increasing our economic ability to fund less affordable methods.

I will limit my remarks to the subject of the built environment, my own field. It is however a large field. Humanity renders the planet useful to itself largely by creating the built environment as modifier of the natural environment. The carbon dioxide (CO_2) emissions from the operation and construction of the built environment, excluding transport around it, are about half of all global emissions. Half of all humanity now lives in cities, and cities are growing at an amazing rate. My definition of the built environment is that it comprises the property, construction and facility management industries, linked by design and management activities, and that it represents about 15-20 per cent of GDP and 77 per cent of national fixed assets. We create, manage and trade this nexus within which all our activity takes place, without it impinging deeply on most people's consciousness that this economic and environmental elephant exists. Its qualities determine the effectiveness and efficiency of much of our activity, from office productivity to patient outcomes in hospitals. It also sets the quality of life indicators for most people, defining their home territory and generating love or loathing for it. I want to explore ways of bringing the value of the built environment into the consciousness of decision makers, and in such a way as to enable decisions on what to build to be sustainable economically as well as environmentally and socially – in the current Treasury parlance, 'best value'.



Value is a slippery word. We use it in many contexts, implying tangible and intangible qualities. It is often used loosely as a synonym for cost whereas value is really the relationship between benefits received and costs incurred. Value is what you get over what you give to get it, in monetary and non-

monetary terms. Good value implies a positive difference between what you get and what you give up to get it. But the yardstick of value is specific to the person making the judgement; value derives from the values of the judge. In a building project there are many stakeholder groups, each with a different agenda of benefits sought and of resources with which to get them. Stakeholders vary in their power to get what they need, but I contend that the most sustainable developments are those which provide positive value for all stakeholders. A commercially successful property redevelopment depends ultimately on the success of the occupier organization as rent-payers and of the location developed as an attractive element of the city. The occupier's success flows from that of their staff and their customers, as enabled by their facilities. The local authority's success lies in providing their voters with economic opportunity, social inclusion and a satisfactory environment.

All these stakeholders are seeking mixes of different and overlapping kinds of value, six kinds in the view of Sebastian MacMillan (*The Value Handbook*, 2006). There is:

- use value, the functionality and economy of the building in service of its occupier;
- image or perceptual value, the communication of identity and status;
- cultural value, the quality of the building as a work of art and bringer of a sense of place;
- social value, the contribution of the development to community needs and its accessibility to all;
- environmental value, its impact for good and ill on the natural world;
- asset value, the exchange value available in the market.

Edward de Bono published his own *Six Value Medals* in 2005, not aimed at the built environment but very similar in thinking as a way of assessing tangibles and intangibles:

- silver medal – the values of companies, embracing exchange and performance factors;
- steel medal – quality values stemming from how well the item is designed and made;
- gold medal – reflecting human values;
- brass medal – perception or image values;
- wood medal – for environmental values;
- glass medal – for creativity.

The best way to define what a building should try to do, to make the brief for the designers and builders, is to reveal stakeholders' agendas for the project and then to negotiate a shared 'value

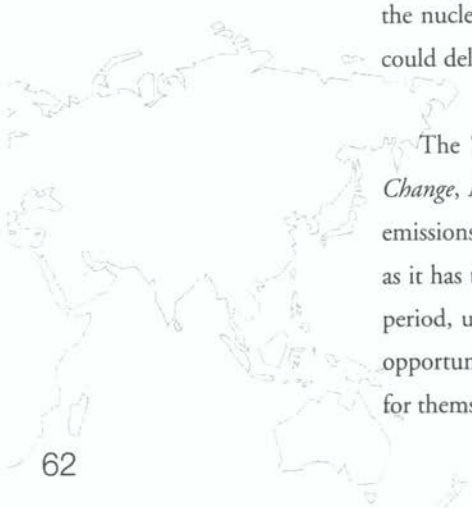
proposition': a statement of what will bring the best overall value and of the resources worth investing. There is a promising technique in use today called the Design Quality Indicator (DQI), which provides a basis for stakeholder discussion of what qualities are sought and assists judgement of designs put forward as to whether they meet the targets. It uses a modern version of the Roman virtues of functionality (*commoditas*), build quality (*firmitas*) and impact (*venustas*) as its framework, asking stakeholders to select the quality levels and weighting of about 100 factors which they consider will deliver the desired results, then judging proposals and finished buildings against them. I maintain that judgements of quality can be made more objectively than is usual if the 'value proposition' is established. Relevant qualities can be defined as those which deliver the desired value.

How should one decide on the right amount to invest in a building to achieve best value? The typical pattern is to start with a budget based on the allocation of available resources, informed by the outturn capital cost of similar facilities with an overlay of thought about issues related to the site considered. There is hardly ever any consideration given to the operating cost budget or to the value of the building to the occupiers, other than in asset value terms where that is relevant. Yet a building costs typically three times as much to live with over 20 years as it does to design and build, and it supports occupiers who will add 30 times as much value to the economy over those 20 years as the original capital cost. Surely the right amount to invest will be that which best supports the occupiers' success and minimizes their cost of occupation, subject to getting good return on capital and to the uncertainties of the planned period of use? The right amount to spend to minimize climate change damage can similarly be judged by pricing carbon emissions into the equation and by considering how the building will adapt as weather conditions worsen.

Many campaigners against climate change treat the goal as one which is overwhelmingly valuable; a matter of life and death without the need for an affordability test. They face the 'business-as-usual' lobby that fears that the economy, and specifically their line of business, will suffer if they are made to invest uneconomically. George Bush's position is that America cannot afford to invest to avoid a long-term future problem which no-one has proved to exist. The conventional tests of affordability simply don't deal with long-term issues, or with externalities, issues which cost society but do not fall on the project budget. Sir Nicholas Stern called climate change 'the greatest and widest-ranging market failure ever seen' in his recent report to government. He makes the case for annual investment of about 1 per cent

of GDP for the next 40 years in reduction of CO_2 emissions to a quarter of their present level per unit of GDP by 2050, to avoid a possible annual loss of 20 per cent of GDP and severe societal problems. He is quite clear, however, that this investment must be made in the most economically affordable way possible, and that it may well turn out to be economically advantageous in the short term rather than a drag on the economy. He recommends regulation, to push investors to do the right thing. But he also wants investment in technology to provide us with cost-effective ways to meet the goal. Economics won't be separated from environmental sustainability. We have to make it economic or it can't happen. It's the developed world's equivalent of poor people deforesting mountain slopes to stay alive. They can't stop to save their long-term future as that would be suicide now. Jared Diamond's recent book, *Collapse*, follows the fate of several isolated societies in history which destroyed themselves by degrading their environment. They could not avoid their fate as they did not have the insight or resources to do so. We now have insight, but Stern and others know we must proceed in an economically sustainable way if we are to become environmentally sustainable. The cost will be greater if we procrastinate, so the best investments will be the earliest.

However, we have great divergence of values out there in the community on how best to mend our ways. There are those who call for massive change in our lifestyle, eschewing air and car travel, air conditioning, industrial farming and world trade. Were it widely adopted, this would cause considerable damage to the world economy and so be unsustainable. What will prevent this are social sustainability factors: there is massive popular resistance in the developed and developing world to any curtailment of aspirations to the modern lifestyle. At the other attitude extreme are those waiting for the technical fix, the nuclear or hydrogen economy which would enable business-as-usual to continue. Their approach could delay the serious reduction of emissions and raise the stakes alarmingly.



The 'contract and converge' model (*Contraction & Convergence: The Global Solution to Climate Change*, Aubrey Meyer, 2000) suggests a timeline for developed and developing economies to reduce emissions to a sustainable level in the mid-century. The developed world needs to reduce emissions now as it has the scope and resources to do so; the developing world is expected to increase emissions for a period, until it too can afford the methods we will have developed to scale them back. An economic opportunity for the West is to develop the technologies which will make low-carbon living affordable for themselves and then sell these technologies into the developing world as their affordability increases.

The UK Treasury is making significant moves towards linking economic and environmental sustainability, although it has yet to formally respond to Stern. It has established the policy that all public-sector capital investment decisions shall be made on a best-value basis. It has now elaborated that requirement in relation to public building investments, 52 per cent of all those made in Britain by value. I am a member of Working Group 2 of the Public Sector Construction Clients Forum, chaired by David Adamson, lately director of Cambridge University's Estates Management and Building Services unit, developing a supplement to the Treasury's *Green Book* of rules for investment appraisal to make it more useful for whole-life building investment decisions. The National Audit Office and the Local Government Audit Commission use the *Green Book* to test whether public servants have done things the right way in the event of trouble. Avoidance of the auditor's wrath is one of the few things that does steer public servants' behaviour.

In the *Green Book Supplement* we call for budgets to be set on the basis of best value over at least 10 years' operating life, with CO_2 emissions included in the costs at a starter sum of £70 ($140) a tonne. With the Treasury discount rate set at an historically low 3.5 per cent, thanks to low inflation, operating costs will count significantly towards the budget. We hope that the *Supplement* will spur clients to optimize the value of their buildings to their users and reduce their whole-life costs. The approach improves overall economic performance and thus creates resources to apply to environmental investments with suboptimal returns. David Adamson's experience at West Cambridge in having the William Gates Building designed for very low operating costs was that it raised capital costs very little. Design costs may well be higher: it costs more to think unconventionally. However, the conventional ratio of design and management costs to capital cost is about 1:10, to life-cycle operating cost about 1:30 and to occupier value added about 1:300. Better design should pay by improving on those ratios. As part of the *Green Book Supplement*, we also seek proper feedback from buildings in use, to provide guidance for future projects on what actually works and is worth the money.

There remains the problem of political affordability. If it is going to cost more capital to deliver better-performing buildings with low life-cycle costs and carbon emissions then there won't be as many buildings funded initially. The savings on operating cost will, if properly accounted for, replace that funding in due course. But there could be fewer schools built for some years than under the lowest-capital-cost regime. Mechanisms like the Private Finance Initiative help the government to afford higher

capital expenditure/lower operational expenditure projects: the unitary payment rolls them together. This could have happened already but has not, due to disincentives to integrate facility-management thinking into design.

There is also a problem in making many existing buildings sustainable. Whilst it may prove affordable to create low-carbon new-build, it costs far more, if it's practical at all, to retrofit existing buildings to the same standards. Grants and loans are needed. These have appeared in the United States of America as loans from utility companies who have found that it is cheaper to reduce demand by a kilowatt than to increase capacity by the same amount. The scale of the retrofit needed for low- or zero-carbon performance is substantial. Historic character can be lost in the attempt. The argument that existing buildings represent embodied energy and should be conserved falls down when refurbishment costs are too great and effectiveness limited. The new generation of buildings needs to be 'long life; loose fit; low energy', to revive a slogan coined by the late Alex Gordon, RIBA President in the 1970s when awareness of the energy issue really began. Generous, sturdy building shells, shaped to be naturally lit and ventilated without overheating, will be able to last through change of use. Arup's marvellous plans for Dongtan, the new city outside Shanghai, envision a city without traffic noise or fumes, thanks to the exclusion of all but electric vehicles. Its buildings are thus able to stay comfortable with levels of power available from ambient and local sources. Dongtan is however a gamble that we will succeed in avoiding major sea-level rises: it is sited in the flat coastal zone and would be among the first to succumb.

We are not likely in the United Kingdom to make zero-carbon buildings pay for themselves purely by saving fuel costs or even carbon charges. We have to create surplus value by designing much more effective buildings for users, more functional and less costly to operate and change. This will expand the resources available overall and help to finance more marginally economic systems like solar electricity or fuel cells without dragging down economic performance. Commercial buildings will need to justify higher rents and public buildings will need to show better outcomes. All the new and various ways of assessing value and making good decisions will have to come into play. Much better building operation techniques will also be needed: many clever designs simply don't perform because they are left to ordinary mortals without instructions or training. Energy labelling will name and shame the poorly run building, but we have to design our way out of reliance on scarce skills.

I have attempted in this lecture to show that environmental sustainability in the built environment will be delivered if we can make it affordable, not just because some want it. This means development in technical solutions for the world market but it also means development in ways of convincing ourselves. We can use the concept of whole-life value to achieve better performance in all its senses and to release resources for environmental solutions which might not otherwise be affordable. We have to use decision-making tools which overcome the market failure of conventional thinking with its disregard of the future and of externalities. We need to couple progressively tighter regulation with the availability of affordable technical solutions. We have to have answers to the problem of present building stock: we won't get to 2050 on target if we don't refit or replace all of it.

We won't be living in 2050 in the way we aspire to live now. There will have been trade-offs between what we want and what we can have. There will be amazing new possibilities as well as major shifts in what is fashionable. Both the eco-puritans and the 'baus' (business-as-usual believers) will have scored some points. The lockstep principles of sustainability will, I believe, have been amply proved: that you must have economic and social sustainability if you are to have environmental sustainability.

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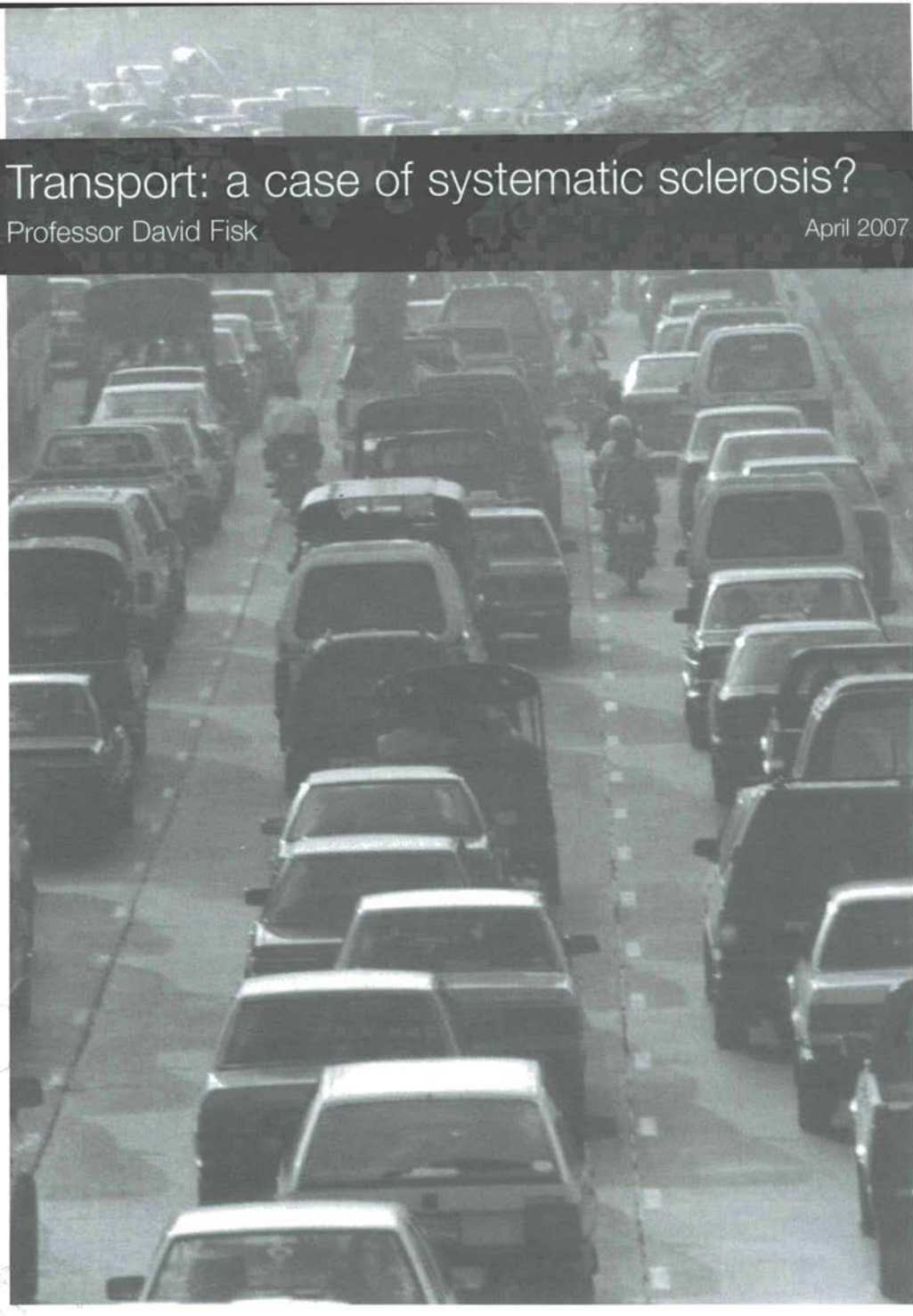
Transport: a case of systematic sclerosis?

Professor David Fisk

April 2007



In 2006 the UK Treasury and Department for Transport commissioned Sir Rod Eddington to undertake a study of 'the long-term links between transport and the UK's economic productivity, growth and stability, within the context of the government's commitment to sustainable development'. This commitment can be taken to be the most recent UK Strategy for Sustainable Development. It is however clear from a reading of the report that the review team had had little time to focus on this dimension of their work. For example, there is some discussion in conventional welfare economics terms of the environmental externalities of transport, but no discussion of the social implications. This paper is an attempt to partially redress the balance. The conclusions are not comfortable.

Poor process and unsustainable development

For simplicity in a self-complicating world, my viewpoint on sustainable development will be that of the World Commission on Environment and Development (the 'Brundtland Commission') in their 1987 report *Our Common Future*. The Commission is often credited with introducing the term 'sustainable development', although a little generously as the term does appear in its terms of reference. The report itself is a series of case studies of areas like energy and biodiversity. It also looks at issues that have since been edged out of the sphere of discourse, like population and arms control. A reading of the Commission's findings is that governments and industry frequently have difficulty handling future issues, and that in particular the pressures to solve today's problems as cheaply as possible tend to encourage shifting liabilities onto others or into the future. In serious cases, these accumulating liabilities can threaten to overwhelm a future generation. The liability is frequently, though not exclusively, environmental because no one takes ownership of the environment. Seen in this context, the so-called Brundtland definition of sustainable development – 'meeting present needs without compromising the ability of future generations to meet their own needs' – which has suffered several hundred restatements (and which has only recently been reinstated in the UK Strategy), actually meant exactly what it said.

Thus this viewpoint focuses on process rather than outcomes. In that sense it is only a subset of a wider sustainable development critique. Terms like 'sustainable yield' or 'sustainable fisheries' seem to have meaning and can be applied critically to real-world policies. The Commission's terms of reference asked for 'a strategy leading to sustainable development', and if it had provided one for transport this paper could have compared it with the Eddington prescription. Instead, a Brundtland viewpoint invites

a less ambitious approach. It looks for dysfunctional processes that do not properly manage future liabilities. What Brundtland would expect us to find in conventional transport analysis are mechanisms that exaggerate the immediacy of immediate problems and dim the future consequences of proposed solutions, shifting the pain of externalities away from those who reap the future benefits. I offer evidence of these characteristics in the conclusions of the Eddington Transport Study.

Some preliminaries

The Study is a review of evidence, not new research, although some new studies were undertaken in parallel. Where the following text is critical it is therefore critical of transport analysis in general, not Eddington in particular. The Study first takes a high-level view of transport and the economy. Having concluded that transport investment can assist 'competitiveness', it then looks at some specific issues of current and future transport networks. The methodology used is almost exclusively in the 'neoclassical' economics tradition that dates from the modernism of the 1960s. Engineering issues appear only through reported costs. The criticisms in this paper are almost all traceable to well-known problems caused by applying general equilibrium economic models designed to describe the economy overall to real economic events in specific economic sectors where natural monopolies and sparse information are abundant. To make it clear that this is not a tirade against economics *per se*, there will be frequent unjustifiable assertions as to what a classical economist might have said faced with the same evidence! The paper concludes that while some of Eddington's findings are unchanged, even when explored in a sustainable development context, some outcomes become indeterminate and other findings are reversed.

Before looking at Eddington's conclusions in detail it is useful to look at the question the Study was set. It is safe to conjecture that Adam Smith would have thought it academic. In his time, transport infrastructure largely engaged private landowners and they bought as much of it as they thought they needed to develop their land. There was no issue regarding whether transport infrastructure added to the economy – if it took place it did. The same argument reappears 150 years later in Coase's so-called 'theorem'. Coase argued that if all property rights were allocated beforehand (and that would include the right to a good night's sleep as much as to a tract of land), then the resultant bargain between property holders could not be bettered. Indeed, we can find instances in the history of transport where such bargains were struck. Stephenson driving his rail line to London had to tunnel underneath the Earl of Essex country park at Watford as the only method of passage for which he could get agreement. The cost

in today's money was some £10 million ($20 million). It was the longest tunnel on the whole line and a sizeable portion of the costs of the Euston-to-Scotland railway.

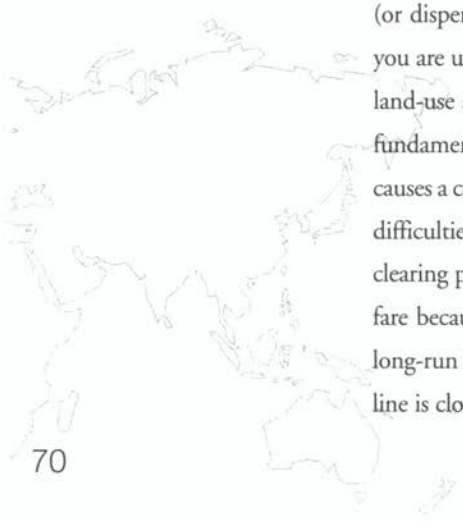
In our more enlightened times, governments seem rather reluctant to put themselves out of business by clarifying property rights, and we can see that the question is in some sense a first sign of dysfunction in government machinery. Once transport infrastructure is funded by taxation, or even worse by government borrowing, the question becomes real – 'Does taxation-funded transport add to the economy?' Governments may under- or overinvest in transport, because they themselves are proxy customers and do not, apart from the military (the 'Ordinance Survey' still maps the road network), need 'transport' themselves. Indeed, it is hard not to read 'between the lines' in the Study a concern, presumably by Treasury, that given the total funds distributed by the Department for Transport, was the current outcome of investment really an optimal balance between transport modes, whatever 'optimal' might mean? Then finally there is the issue of whether government has compensated those who suffer the social and environmental externalities of the investment or simply transferred wealth from one sector to another without compensation (as all governments tend to do).

If, like Eddington, we sharpen the focus of 'transport' costs to the resources consumed in moving goods and people from one place to another, transport is clearly an intermediate good. The proportion of transport used as a final consumption good in its own right (with the 'drive in the country' long-since passed, only pleasure cruises come to mind) is insignificant. The consequence is that once an economy is 'developed' in the sense that everywhere is connected to everywhere else, then the fewer resources devoted to transport – 'everything else being equal' – the more productive the economy. For example, China's coal reserves are a long way from where the fuel needs to be burnt to power industrial production. This transport requirement reduces China's industrial productivity compared with a country where energy resources are adjacent to point of use. There is an analogous position in energy discourse: energy analysts assume that expanding energy supply is a prerequisite of a healthy economy, but the transport economy sees energy as an intermediate good. The less energy a transport undertaking needs to move goods and services, the more productive and competitive it would be. When Eddington uses 'time saved' as the immediate return from infrastructure investment, the Study is arguably subscribing to the intermediate good proposition, although this is not the tone of the bullish conclusion of Chapter 1 of the Study. There is a further classical twist. If transport investment is to increase the productivity of a specific location, how

do you stop (if you wanted to) the gains being collected in increased ground rent? *Wealth of Nations* and *Das Kapital* agreed on at least this – it is near impossible.

Transport seen as an intermediate service is rather more complicated than energy. While some journeys can take place any time, normally students have to arrive when classes start, passengers have to arrive when trains leave, goods have to arrive when the warehouse is open to receive them and so on. The service is thus partially 'socially constructed', which presents some algebraic difficulties for those inclined to general equilibrium algebra. Most transport modes for a given infrastructure have declining economies with scale of use because journeys simultaneously using the same infrastructure interfere with each other. This 'repulsion' effect as travel density increases is a key issue in urban economic models. The diseconomy progresses up to the point of severe congestion where almost no travel takes place. For example, because of the volume of travellers it is perfectly possible to spend more time on the ground stretch of a Delhi-to-London flight than in the air. Times from Central London to the centre of Paris were faster in the 1930s than in the 1990s. Where congestion occurs stochastically, the average travel time may be less important as a product characteristic than predictability. Reducing the average time to reach an airport is not generally helpful in catching the flight if the long tail of M25 congestion remains. Valuing journey changes just by 'time saved' is clearly a drastic simplification.

Formally, the market need for 'transport' is a consequence of an interaction between non-adjacent differentiated locations. If all locations were identical, there would be no motive for transport. So transport technology actually adds to the productivity of the economy's assets by permitting gains from clustering (or dispersion). Clustering housing together makes it easier to have a nice place to live (unless of course you are under a flight path). It is common to speak of 'land-use/transport interactions' in a context of the land-use adjustments that take place after an infrastructure improvement. But this rather underplays the fundamental nature of the land-use driver that was much clearer in the 18th-century case. This driver causes a complicated response time structure to changes in transport costs that present some special analytic difficulties. The short-run elasticity will normally be very very high. As an extreme example, the market clearing price for taxis after a lightning strike on a commuter line would be vastly higher than the normal fare because (interacting) workers and workplace are instantaneously widely separated. But the ultimate long-run elasticity is very very much lower. Workers and workplaces readjust their locations if a commuter line is closed. There is thus a risk that we overestimate the long-run value of transport if we do not follow



through the analysis to equilibrium land use. Land use unfortunately adds its own analytic problem because, as Paul Krugman at Princeton argued, the land market cannot be assumed to be even approximately ideal competition. Place is by definition a local monopoly. Later this paper will look at the relationship between transport infrastructure investment and the rent-seeking behaviour of landowners.

More broadly, there is an even more general problem in answering the Study's question with the term 'economy'. In the late 18th century, Smith – 'the last solar-powered economist' – is observing a relatively simple economy with few layers of intermediate production. By the time of Marx, while the economy is still conceptually simple, in practice to calculate the 'labour value' of a product requires wrestling with inverting input-output matrices, not just counting the number of labourers attending a pin-making machine. By the time of Keynes, 'the economy' is being presented in economics almost as a thermodynamic system with myriad microstates brought together 'at national level' by aggregate economic data such as national product and unemployment levels. In this 'thermodynamic' viewpoint, it would seem legitimate by physical analogy to assume that there could be differential (marginal) relations between these aggregate quantities as there is for example between the pressure and temperature of a gas of countless molecules. None of these ideas loses legitimacy as models of economies, but it would be hard to deny the proposition that on the ground a modern globally trading economy is a complex system *senso stricto* as argued by Paul Ormerod. Indeed, the Eddington Study demonstrates the point. Like the analysis supporting the 1997 transport White Paper, the complexity of the full transport market thwarts its attempts to complete a fully integrated multimode economic model for the UK land-air-sea transport market. The Study is in good company when it does not even contemplate adding a land-use/transport interaction to its market models, or fit them in a global context.

The Eddington Study concludes that GDP is an appropriate indicator for the 'economy'. As far as 'the government's commitment to sustainable development' is concerned, the Study can pray-in-aid the government's own sustainable development indicators (SDIs). These indicators use GDP to measure economic growth, although something odd seems to be happening, since all the economic indicators have recently been relegated to 'contextual'. GDP has been criticized (e.g. by Dasgupta and Pierce) because the index can increase (as in time of war when money is borrowed and spent on armaments production), yet no citizen (except perhaps armament manufacturers) sees things getting better as warfare destroys the capital stock. It is also rather telling that the Eddington GDP is not normalized per capita. It could be

increasing simply through population growth, and then even when the average citizen is getting poorer, as is not uncommon in large-scale migratory movements. 'Population' has only recently appeared as a 'contextual' indicator in UK SDIs (it has been in the United Nations template for indicators for years), which is strange since variations in current projected increases are largely the result of alternative government policies, not private family planning. However, the really telling question is why only one measure of the economy is thought necessary.

For example, it would be extreme to use one index for the state of the environment or social capital or the health of the nation. If statisticians begin to create a composite index, it soon becomes evident that the battleground is in the weighting factors of the different components. Someone buying a company would want to look at the books, both the profit and loss account and the balance sheet – not just a single figure of merit like price-to-earnings ratio. Since the Brundtland critique is looking for creation of future liabilities, there could not be a worse single SDI measure than GDP, since this says nothing at all about the state of the assets. As Joseph Stiglitz points out, GDP could be high simply because assets (like North Sea oil) were being sold off. Net domestic product would have at least measured product after covering depreciation of existing assets. The United Kingdom did produce a trial set of National Environmental Accounts in 1997, but the exercise has not been repeated and is not referenced by Eddington.

The truth of course is that what 'the economy' is depends on viewpoint. GDP (and even more GNP) measure total economic activity in the 'legitimate' economy. It is therefore as Treasury sees the 'economy' (in the sense that if you can count it you can tax it). Since Treasury provides the SDIs for the economy it is no surprise that GNP appears there, but a little more surprising that the index has not been fiercely challenged. It also reasonably well approximates to the viewpoint of the very rich (i.e. as a measure of the nation's potential rental base). But it would not be expected to be how the economy looks to, say, a worker in a lower socioeconomic group. As Joseph Stiglitz has pointed out, in globalized economies using active interventions to control wage inflation, GDP hardly correlates with lower decile incomes at all. Many large developing economies have taxation bases that can afford satellite launchers and state-of-the-art military expenditure, while the poor see little of this wealth. The argument against the single index is traceable back to at least Malthus, who objected that Smith ignored the composition of national income when he assessed 'wealth'. The issue of composition even has bearing on transport projections. A richer nation could spend its money buying a new fashion watch every month or just a Rolex for life, with rather

different implications for road-haulage use. This paper will later argue that because GNP has been manoeuvred to be the index of choice, the Study by design does not pick up transfers of assets from poor to rich as a consequence of transport infrastructure investment. Similarly, the manoeuvre shuts down discussion about a particularly worrying off-balance-sheet liability in the form of future energy security.

The Study sometimes talks informally about productivity and competitiveness. If you are running a business the meaning is pretty clear. If you are uncompetitive you do not win orders. But as William Baumol has argued, preventing competitiveness (used in contrast to competition) from becoming destructive is as much a function of government as is avoiding the formation of monopolies. Unfortunately, governments are a little prone to lobbying so that they seek to be in trade surplus in everything! Consequently an industry might be internationally competitive (as in US agriculture) because taxpayers cannot find a way to stop it being subsidized. As a consequence, the overall economy performs less well. Destructive competitiveness is one common element in unsustainable development ('we just cannot afford to be sustainable'), but to be fair to the Eddington Study, it is not one created overtly by its style of analysis. Civil engineering and transport undertakings clearly see chucking public money at transport as improving competitiveness, and the analysis Eddington deploys is designed to be sceptical and see if they were right.

Eddington and history

What is evident from these extended preliminaries is that the questions posed to Eddington are not trivial and could have answers either way. Eddington commissioned a historical review of transport and the economy, and while fascinating, the arguments above show that unless one could assert that the structure of the economy was the same in the time of Smith (canals) or Marx (steam railways), in a modern economy (container ships and jumbo jets) the question as to the role of public investment in transport remains open to observation; the past is no guide to the present. Eddington actually conjectures that no future leap in economic activity is expected through transport. The earlier analysis here would concur because in its terms there are no new places left to access. It is not the means of transport itself but what can be accessed (e.g. the Chinese industrial sector via container ships) that creates the wealth. Significantly in the historical perspective, it was the technology of international transport that continually avoided 'limits to growth' by importing solutions and exporting problems. Space technology is arguably the next wave of transport technology but, apart from placing satellites in orbit (a not inconsiderable contribution to the world economy but out of scope here), there is nowhere new 'out there' that is profitable to go.

The Eddington Study draws an important conclusion for sustainable development from the recent academic literature. The relationship between transport infrastructure and the economy is not a matter of one leading the other. This conclusion is in distinction to ideas in the 1960s often labelled 'predict and provide'. In this model of public intervention, a macroeconomic relationship between a utility and an index of the economy is deduced from historical data. The government sets a future value for the index by dictat and then invests to close the gap between existing utility infrastructure and predicted. If the marginal cost of using the utility is low, demand will fill the new capacity – and the prediction algorithm will be fulfilled. The problem, of course, is that the method never incentivizes efficiency and runs roughshod over the externalities created by the utility. It has a long post-Great Depression heritage, with the construction of the Autobahns by Hitler seen at the time as a positive intervention to reduce unemployment. By 1997, when the UK government rejected the concept in transport planning, most infrastructure development was already in response to congestion rather than anticipating 'planned growth'. But presumably we can assume that artefacts like the United Kingdom's unique position on untolled motorways (the reason cannot be land-take, considering how much the motorway system has now taken since the 2+2-lane M1 was opened in 1976 from Watford to Luton) are signs of a past belief that the burden of proof favours transport infrastructure development. Eddington's conclusion on the neutrality between investment in transport infrastructure and the economy is therefore more important than it is given credit for in the Study. It essentially reverts the approach to public investment in infrastructure to the classical model and favours scheme-by-scheme analysis rather than national five-year plans. The sustainable development analysis here can only concur, but with the regret that no apology for past overinvestment is offered!

Valuing investment

Eddington values the benefits of an improvement in infrastructure by associating a value to time saved by travelling the same distance faster. These values are imported from estimates of the marginal value of time for private and business travellers. This is a model of the true valuation. There is clearly some disjunction between the imputed marginal value of time (effectively the opportunity to do something else) with the practicalities of when the travel savings actually occur. Travel diaries remind us that travel is frequently socially determined – the school day has to begin at a set time, trains have to leave on schedule, factories have to be open for delivery and so on. For journeys for which the arrival time is critical, it is easy to conceive of situations where reducing the dispersion in journey times (i.e. increasing the predictability) is more

valuable than reducing the mean journey time. But, more fundamentally in the context of this critique, this valuation method omits the actions taken by other economic players in creating or destroying assets.

For example, consider a firm that provides geographically located services (e.g. banking) that show economies to scale. The firm tries to cluster the service as much as possible, extending as far as possible the travel times of the marginal customer. Increasing travel speeds, say by providing a ring road, provides the opportunity to close some smaller clusters and build up larger clusters without losing customers. The customers needing the service never really had the opportunity to use the time saved. A well-documented example took place at Cribbs Causeway. The flagship retail group, John Lewis, closed its Bristol city centre store and relocated it on a site at the junction of the M4 and M5 to the north of the city, well connected via the M4 to the city's western and northern suburbs. The Study reports some new work by Daniel Graham that is some of the first to measure clustering gains. But it does not venture the possibility that these might sometimes be the only gains (and taken largely by landowners, not travellers). Another example is in modern distribution systems. The FedEx distribution system is a US success story, but not through thousands of short journeys across its network. Instead, overnight deliveries are all brought to a hub in Memphis, and then redistributed. This ensures high capacity of planes and greater dependability of available aircraft. Since the service is 'overnight', buying supersonic airplanes does not make it any more profitable. It means that, care of the UK road network, 'locally produced' vegetables in a supermarket will have had a round trip of several hundred miles via the central distribution site before they arrive on the shelves.

What is happening here is fully consistent with the classical case. Transport infrastructure is increasing the wealth of landowners. The only difference is that they are not paying for it. To try and quantify what is happening is a formidable task. In the Study, all the time saved was disposable at the discretion of travellers. Based on travel diaries this is hardly tenable, so let me take the alternative extreme view by assuming that investment by landowners in the long run means no new time is available. The evidence follows on from travel diaries. Yacov Zahavi asserted that realized travel times were invariant and remained constant (about 75 minutes a day). Essentially, infrastructure improvements change speed of travel, not time of travel. Recently, Robert Köbl and colleagues at Southampton have refined the argument by estimating the physical energy used by the traveller such as the strap-hanging commuter. Their argument is that the practicality of modal choice will reflect the constraint of how tired travellers

can afford to be when they arrive. They estimate an energy budget of 600kJ/day with even less variance between travel budgets. These 'constants' imply around a 100 per cent rebound effect for some transport infrastructure development. This is of course hardly remarkable in economics. It is what is assumed in discussing increased labour productivity (i.e. other employers seek to take up surplus labour and increased speed means more deliveries, not fewer van drivers). More to the point here, it offers a way to understand how the land developer will view a change in travel speeds.

Developers working with a rule of thumb taken from experience or travel diaries will see an improvement in travel times as an increase in the total goods and services that can be accessed from their land. Let me go to Houston, which provides a textbook case because it has little or no planning controls. When the Katy Freeway is completed west of Houston, which at 24 lanes will be one of the widest freeways in the United States, the effect is to open up more land for commuter housing to the west, not more time with the kids. Clearly in an underdeveloped country (as indeed Sweden was at the time of Malthus), investment in transport infrastructure reaps real returns as productive land is brought into the economy, but the issue is more subtle in a developed country where in principle everywhere is connected to everywhere else. Eddington correctly raises a caution against the expectation that increasing the connections between two places necessarily raises the prosperity of both. This was another 'bright idea' of the 1960s. Ricardo is usually attributed with the theory of comparative advantage in trade between two regions, and he would have seen why. An investor might have dreamed that widening the A30 in the far west of Cornwall could create a new business park sending goods east. Ricardo would not have been surprised that the road simply moved the comparative advantage of small local industries to larger businesses to the east, and at the same time provided local warehouse space for more easterly firms already nearer larger markets.

The same argument applies to freight. Saving time for freight traffic is not more deliveries per van, but concentration of warehouse facilities. There is an economic gain here of course, but one that varies roughly as the square root of the warehouse area (from reducing stock variance), not value of time. Many retailers would like to use one central warehouse. Whether Eddington's just-in-time argument applies to the productivity of a service economy is another matter. The indicator of congestion used throughout the report is a road running at 80 per cent of free-flow speed. That is a contender, but an indicator more consistent with air or rail would have been reliability of journey time. The free-flow congestion measure

invites 'sweating the asset' with technologies like hard-shoulder running and peak spreading. Perversely, this actually risks pushing reliability outcomes in the wrong direction because reliability needs redundancy in the network. In systems theory, optimality and resilience are trade-offs against each other, and attempts to minimize costs in transport lead to increased variance in service delivery. This was the case with the early days of rail privatization and is certainly the case with many parts of the global air network. Taxpayers should be very suspicious as to whether 'sweating the asset' is really to intensify the congestion.

Collateral damage of transport investment

The area around Watford provides some interesting examples of contrasting approaches to the externalities of transport. Watford seems to specialize in being 'typical' to the point of being inundated with pollsters at election time, but for the purposes here has had transport investments from canals, rail, the North Orbital, the M25 and even a small airport. The rebuilding of its theatre is a typical set of decisions of anyone investing in land use. The theatre management could argue for an increase in seating capacity because the audience reach within around 30 minutes travelling time had been recently increased by a link road through a local park to exit 5 of the M1. The 30-minutes rule used by the theatre management is not capricious. A two-hour evening entertainment has to fit between when the audience returns from work, when they eat, and when they need to get home for sleep. They need to arrive fresh enough to enjoy the evening. The new audience is probably at the expense of smaller local venues, some of which will close. Now it could be that someone able to stay at work for 15 minutes longer care of the link could earn just enough extra to afford a theatre ticket, but they are not a central part of the land investors' model.

Unlike the world of Smith, where the good burghers of Watford would have had to buy the right to drive the road through the park from its owner, the theatre did not contribute to the new link road nor does it compensate the dwellings close by for the loss of amenity of their park or the nighttime noise. Indeed, while welfare economics often explores projects on a basis of Pareto optimality, where benefits need to outweigh dis-benefits, these transfers are seldom administratively realized. Until the 1970s, Parliament had not even given the executive the powers to pay compensation for those suffering from infrastructure 'improvements' (actually after the residents adjacent to – as in bedroom windows facing onto – Westway stopped the opening ceremony). A classic case was the semidetached housing cut in half by the widening of the North Circular Road because no parliamentary authority existed to buy land

that was not to be covered by tarmac. But then the Normans never asked the Saxons for planning permission to put up a castle.

As a consequence, the dominant effect of transport infrastructure investment – as far as other environmental and social capitals are concerned – is usually transfers from those with low-to-modest incomes to everyone else, and landowners in particular. All valuation techniques are by their nature a little fuzzy but, as we would expect from the above argument, they purposely err on the parsimonious as far as judging the bads of transport. Most of the environmental externalities valued in Eddington use 'willingness to pay' estimates rather than (as with the Earl of Essex) 'willingness to accept compensation'. The latter is usually about three times larger and wipes out a noticeable fraction of the 'economic' transport cases explored in the Study. The consequence has been around 40 years of what historians may well later view as legalized vandalism in both the urban and natural environment, for which Brundtland would not be surprised that the nation has never found the funds to remediate. The Eddington report's habit of talking down, or sometimes not mentioning, these downsides, is fully in this tradition. While growing the economy, transport for over a hundred years has been blighting the asset value of low-income housing.

Transport-related land development

Let me return to the issue of land development and transport infrastructure, but this time not the extension of commuting but the development of extra trips. One of the earliest examples was the proposal to build a large retail complex at junction 21 of the M25 as soon as it was completed, a development that had not figured in the original traffic flows presented to the planning inquiry. Time budgets were clearly the attraction, with a new market of around 3 million in range, although at the expense of local town centres. That enterprise failed at the planning inquiry stage, but other examples soon emerged, not least the shopping malls either side of the Dartmouth crossing. Possibly the classic example of provocative land use was Cribbs Causeway at the junction of the M4 and M5.

Again using the time budget, the M4/M5 junction is an obvious place for a large retail centre. The M5 after all sweeps round the whole west side of Bristol. For a while the land use at the junction had followed the classic rule of warehousing, but a Carrefour hypermarket created a chink that expanded into a very large development. It is usually notoriously difficult to establish that one retail development degrades another. It is for example hard to find out if rents have changed to accommodate competition.

But it is hard not to attribute the economic difficulties of Bristol's commercial city centre to the Cribbs Causeway development. The strongest evidence is that John Lewis Partnership, a commercial anchor store, closed its Bristol centre branch when it opened its flagship store at the motorway junction. Because we see transport in terms of time saved, not land use, this kind of story repeats itself many times over. The Bristol centre has arguably been regenerated with public money, but this seems a very roundabout way to run a sustainable major city.

Britain has seen a remarkable drop in its number of shops, and in many areas local shops have seen little of the nation's economic growth. Often all that is left of a small urban retail cluster is the hairdresser and the tobacconist. The style of free transport infrastructure provision must be part, if only part, of the story. Bizarrely, English village commercial life only seems to exist in rich enclaves in large urban centres that have retained some through traffic through wise estate management. Many tourists will have noticed that Georgetown in Washington is a vibrant (and expensive) middle-class community, but one that purposely does not have a metro station or freeway exit.

To be fair, examples do exist of using transport investment to provoke a desirable land-use outcome. The Houston Metrorail is an example from an unexpected quarter. Trams are usually viewed in transport economics (and Eddington) as poor value compared with buses, and are certainly less flexible to deploy. But to the land investor the inflexibility is actually the point. No point risking investment in Salford Quays if the capricious whim of a bus company can lose the connection altogether or Jim's Clapped Out Bus Company wins the franchise. Houston does not have a downtown traffic problem. Indeed if it has a problem it is that there is no downtown traffic (except for an unsavoury Greyhound bus station). The Houston Metrorail has served as a regeneration corridor along the full length of Main Street. The UK Department of Transport has funded a study of the Croydon Tram, but the rather inconclusive outcome is presumably because of the complicating factors rather than the benefits. The Eddington Study picks up none of this land-use gain, so not surprisingly ends up in a love affair with the bus.

Urban transport

Eddington notes that there is little projected growth in urban traffic levels. Then if all this transport investment is to make us more efficient but not much happens in cities, it is rather a mystery as to where we are exactly making all this extra GDP. The time-budget model above of course tells us that city

congestion is self-limiting, with the lower limiting speed for personal travel effectively the total time of a public service journey. London traffic has moved at around 13-15 mph (21-24 kmph) for years, which is about the speed of an Underground journey if you see it from the traveller's point of view, not Transport for London's. Unless a congestion charge is so high as to make motorists penniless, its main role is to speed up the bus system. Drivers are right to complain about empty bus lanes, not because they are unused but because they imply slow average bus journeys. So it is that urban land use adjusts appropriately.

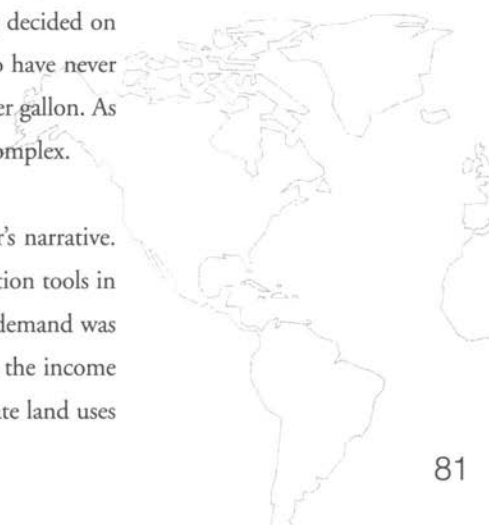
Much of the land developer's point of view is captured by following through a time-budget model. An urban area is characterized by the travel time budgets to critical services (say the local shops). On a dimensional argument, the scaling relationship from different urban areas needs to have the mean speed of travel varying as the inverse square root of the population density. If it is a fast-moving urban area, the developer naturally spreads the area out, if it is slow-moving it has to be packed together. The mean speed would be less than the free-flow speed because of interactions with other travellers. The proportion of the travel budget spent not actually travelling is going to be a slowly varying function of density, because low-density cities have a lower density of travellers but on a physically longer trip. More to the point here, an investor looking to place a service with a particular time budget estimates a market catchment area that is proportional to the square of the mean speed. But since mean speed was roughly inversely proportional to the root of the density, it follows that catchment size varies weakly, if at all, with urban density or free-flow speed. Cinemas are cinema-sized in most of the urban area. Consequently urban speeds would not be expected to have much long-run effect on urban productivity through clustering where there is only one mode of transportation. The conclusion would be different if the investor could persuade the public sector to fund a faster link that did not itself readjust the basic density of the urban area. That is one reason why, in part, out-of-town shopping located on ring roads is so competitive compared to the pedestrian high street, care of the generous gift of high-speed road capacity to the land banks that speculators have sited adjacent to the ring roads.

The Eddington Study believes it uncovered very high rates of return on urban transport projects. We can see one reason why from above. The idea is intriguing because, in engineering terms, urban projects have a reputation for being very expensive. The Boston Big Dig to bury Interstate 93 for 5.6 kilometres costs around $15 billion (sic), making it the most expensive motorway in the world on a per-kilometre basis. Whether, had Bostonians had to pay for it themselves, it would have happened is a moot point.

Economic instruments

Before I end my discussion by looking at Eddington's future projections I should say a little more about the relationship between time budgets and traditional neoclassical models of consumer behaviour. Consumer behaviour is modelled by maximizing a utility function of all possible consumption goods subject to an income constraint and a vector of prices. It was introduced to make the 'big picture' general equilibrium model of the economy analytically tractable – not because of some new empirical evidence that escaped the insights of the classical economists (or for that matter Shakespeare). Almost 50 years ago, Simon cautioned about taking the model too seriously when dealing with detailed microeconomics because the implied optimization was impracticably complicated. Indeed, if you enter Wal-Mart with a $100 dollar bill you would need to have sorted 10^{20} possible trolley loads before you got to the check-out. Making choices is a cost like everything else, and it is presumably why we distinguish in normal speech between 'choice' and 'decision'. If we dream of being rich it is probably about making lots of decisions based on whims, not having access to a thousand mail order catalogues to spend all day making choices. We do not face this problem in reality because we use narratives to frame decisions. Hamlet does try a multi-criteria analysis ('To be or not to be...'), but not until Act III. Up to that point he has made no end of decisions (not to go back to university, not to kill Claudius...) all of which the English literature undergraduate finds totally consonant with the narrative of a young man in a state of high anxiety. Real consumers are a patch of two behaviours: 'rich' and 'poor'. Where they feel 'poor' they make compromises, but where they feel 'rich' they don't. Product marketing has to get this right and it is a pity that we are beginning to isolate some branches of economics from its insights. Budget airline advertisements tell you the lowest price you will never get, car manufacturers put fuel consumption in the smallest font possible. The 'rich' consumer is not price insensitive, it is just that having decided on brand and product, it is only then that differing offer prices come into play. Motorists who have never asked about fuel consumption, when they buy a 4X4 drive on 'empty' to get a better price per gallon. As Simon argued, this is perfectly rational in a complex world. And the economy is certainly complex.

The time budget is just part of this story. It is the physical realization of the consumer's narrative. What is perhaps ironic is that 'price signals' are becoming an increasing part of the intervention tools in transport, when at one time a rationale for the high levels of taxation on vehicles was that demand was inelastic and so the taxation caused little distortion in the economy's efficiency. Apart from the income effect, land developers are likely to ignore them because the degree to which they differentiate land uses



becomes lost in rents. For example, it is conventional to ignore adjustments in rent as a consequence of road charges. Both Smith and Marx would have found that odd, since both found it difficult to see how to get the advantages of a location out of the pocket of the landlord. If you are the owner of a London car park then your charges need to just fill the spaces. If a congestion charge bites into your volume of customers you need to back off your rates to your customers' benefit. There is no reason why this should totally offset the charge but, as with the recent Oxford Street and Regent Street rent negotiations, do not assume that all the congestion charges' short-run, demand-stifling effects will be there in full in the long term. Thank heavens it pays for the buses!

The future

In Brundtland's terms 'sustainable development' is the *raison d'être* of future thinking. Much of the Eddington Study is focused on the distribution of current spend, but it does provide transport 'projections' that go out to 2025. The method computes a 'transport demand' from time series that are supplied externally for GDP and population. Now it is algebraically possible to iterate a capital growth model as many times as you like, but it is normal to rerun the model at least every five years, recalibrating it with the intervening years' data. Projecting capital growth for longer periods leads to problems because of the somewhat arbitrary way that GDP is converted to 'constant prices' when technological progress is assumed. The model has credibility in, say, forecasting over a comprehensive spending review period, but is arguably not the best way to talk about the longer term. In this approach, the future is essentially today only scaled up and physical constraints (e.g. constrained travel times, not everyone can be a truck driver, the 24-lane engineering limit to freeways) do not figure. When constraints begin to bite they influence the model through the recalibration of parameters, but do not form part of the modelling discourse. If Heathrow by 2025 has turned West London into a large *favela* (as the frequent traveller might have noticed can happen elsewhere), we will not know. The best way to boil a frog is slowly to increase the water temperature! This is in contrast to the spirit of Brundtland, which does not require us to model the future accurately, only to identify well ahead serious liabilities and constraints. The Eddington methodology tries to predict the future but without accounting for limits and liabilities.

The use of external series to drive the transportation models is also worth a mention because that may be a further 'Brundtland' failure. In transport we have seen population density as an important determinant of transport outcomes. At a given location density changes over time with migration, both

regionally and internationally. In classical or neoclassical terms, these movements are in part in response to economic incentives that are re-establishing balance across the economy in which there is free movement of people. The 'optimal local density' then only comes about if the diseconomies of inward migration are reflected in the marginal decision to migrate. But in the Eddington projection methodology this feedback is cut off. Commuters complaining that there are too few trains, causing overcrowding, may be confusing the situation with there being too many commuters from new cross-subsidized remote commuting centres. To rub it in, Eddington is using population projections significantly lower than the recent Office for National Statistics projections, though the latter have no economic feedback in them either.

The net effect of all this is that while Eddington discusses the long term, it is done in a way that obscures the important economics of what is actually happening. Thus the projections are subject to a sensitivity test of different constant oil prices. $100 dollars a barrel is the high scenario – enough said. Jevons, who wrote at the very end of the classical period on the issue of UK coal reserves, would probably have noticed something else. It is not that we are running out of cheap-to-produce oil. It is that we are running out of suppliers. What is more (or as a result), the Middle East is a very politically unstable region. The transport sector is in something of denial about all this. A recent Royal Academy of Engineering review overstated the 'time to exhaustion' by almost a factor of two by misreading oil industry data. 'Peak oil' is not even discussed in Eddington.

The land-use interactions that have been described above have had one major effect. They have removed modal choice. Wide car ownership has not meant people drive to the local shop; it has meant because of investments elsewhere that the local shop has closed. In the example above, people who used to walk to their local theatre will now drive to the main town. Since the 1970s, oil has taken over from electricity as the strategic fuel in the economy, at a time when Middle East politics could not be more insecure. A small disruption in oil deliveries in the tanker drivers' dispute causes rational panic buying that empties the entire supply network. It is rational because changes in land use have eliminated travel alternatives for most workers.

Things get murkier. In conventional resource economics we work through reserves in order of increasing costs of production. But oil is a noticeable exception. One of the consequences is that we

have a large reserve of cheap-to-produce oil and an even larger reserve of very expensive-to-produce oil, and not much in between. This is a recipe for an oil price even more unstable than normal commodity prices. It is also a recipe for asset transfer. Once the owners of cheap oil have bought all the Gucci handbags and jet fighters they can manage from the large rents that they are collecting they begin (as in the style of Norway) to buy assets with their income. Now in one worldview this is just trade. But Eddington's worldview is more jingoistic than this ('UK competitiveness...'). We are left wondering whether a prescription for infrastructure investment that leaves us increasingly strategically dependent on oil just as oil becomes more geopolitically risky and – to quote Warren Buffett – that leaves us a sharecropping society, has really advanced competitiveness and productivity for any useful purpose.

Conclusions

The Eddington Study had little time to look at the issue of whether it was proposing a policy suite that was consistent with sustainable development. Indeed if Defra (UK Department for Environment, Food and Rural Affairs) officials had inserted the reference to sustainable development in the terms of reference they might have done better not to have bothered. Eddington is an exemplar of conventional transport economics and rather unfairly suffers here from being the voice of a much larger school of thought. Transport is generally recognized worldwide as an area where the idea of sustainable development has made least practical progress in reconfiguring investment. In the absence of a sustainable transport template, this paper set out with a less ambitious objective of applying a 'Brundtland-style' critique to the Eddington Study that focused on process – how were future assets handled and was the future sold short? It may be that the problem in bringing into being a convincing sustainable transport policy is a fundamental flaw in process, a process that divorces land use from what connects land.

Some conclusions from the Study remain robust to this critique. The 1960s view of transport as a way for public funds to pump-prime the economy is not well founded. Similarly, transport investment can contribute to asset productivity, but unlike Eddington it is less clear if, when all factors are taken into account, anything like the Study's scale of investment is justified by the market. This is because the view taken here is that benefits are largely returns from clustering rather than time saved (because it isn't) and that compensatory transfers for collateral damage never materialize. If the Department for Transport had received public funds for all the projects it judged 'economic', then we could be fairly confident that the

public sector was overinvesting because of biases in the analysis. These are presumably an overhang from a 1960s dogma, creating damage and liabilities elsewhere in the economy.

As in many other countries, taxpayers in the United Kingdom have probably been buying the wrong kind of transport since the postwar years due to an exaggerated belief among parliaments and the executive in transport's medicinal value for other industrial ills. The casualties have been largely environmental and social capital, with the better off largely to gain. 'Twas ever thus. But as we move into tricky waters on global energy, this inherited infrastructure risks being written off as obsolete, and the land-use changes that infrastructure has induced will leave the United Kingdom materially disadvantaged. While the assumption that transport investment leads to growth in economic, social and environmental capitals has evaporated, the whiff of older thinking remains. Nothing is helped by using GDP as a single statistic surrogate indicator, and if that cannot be expurgated then it is hard to see where the brake in the system is to be found. This paper has persistently asserted hypothetical 'classical' economics positions partly as contrast to current orthodoxy, partly to emphasize that the argument is not against economics *per se*, but also to argue for the insights gained by working with a plurality of models. Twentieth-century academic economics has become unhealthily obsessed with making economics look like physics, but an engineer would never be comfortable working with just one model. The integrated circuits in my computer are designed with quantum mechanics and the power supply with Ohm's law, but it is electrons in both cases. For analytic convenience, neoclassical analysis puts a great emphasis on the competitive equilibrium approximation. That may be suited for the big picture, but the world of monopoly and rents is the real world of transport and land use. We need to get postmodern in economic theory if it is to do more good than harm.

It is difficult not to conclude that some part of transport is in fact entirely a land-use issue since it fundamentally affects rents and land prices. There have been two attempts to bring transport and land-use planning together in the UK public sector in the last 30 years, but both failed under centrifugal forces. Arguably, rail safety or seat belts or drink driving have little to add to land planning and could be in a transportation arm of government. What is not so easy to defend is treating the infrastructure of connection independently of the management of what is connected. The recent Royal Commission report on the urban environment comes to a similar conclusion from the other side of the argument. Land-use planning decisions have to take into account transport needs. There is more than one

governance model for such a shift. In the United States, for example, some states have fierce and effective zoning rules that would have precluded opportunistic land development. In other states effective and binding treaties between land developers and land users perform the same task. Capturing 'windfalls' from transport infrastructure improvement, rather than funding it through taxation of players least able to do much about reducing use, would be a start. What we need least is a transport and land-use system chasing independently the wrong economic index in a race between tarmacking and bricking over either the whole country or at least one corner.

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