RS policy document 27/05

Royal Society response to Stern Review on the Economics of Climate Change

December 2005

This response has been approved by Sir David Wallace on behalf of the Council of the Royal Society. It was prepared in consultation with members of the Society's Energy Policy Advisory Group and Environment Advisory Network, along with other experts in the field.

1 Introduction

The Royal Society, in its role as the United Kingdom's national academy of science, aims to influence government policy by providing independent, rigorous and objective science advice on a wide range of issues. This advice is based on the latest evidence and is provided by world experts.

Science plays a vital role in all aspects of the climate change debate – from understanding how our climate is changing to exploring how society should respond through adaptation and mitigation. The Royal Society believes that responding to the threat posed by climate change is an issue of the highest priority and welcomes the opportunity to provide evidence to the Stern Review.

Much is made of the uncertainties involved in the science of climate change. Many aspects are uncertain and global investment is required in the science so as to better inform decisions. However, it is of vital importance that the public and policymakers understand that many aspects of the science are clear. There is strong evidence that significant global warming is occurring and that most of the warming experienced over the last 50 years is attributable to human activities (IPCC, 2001). This warming has already led to changes in the Earth's climate, and continued growth in atmospheric CO_2 concentration will accelerate that change. In short, from the point of view of the science alone, urgent action is justified to substantially reduce net global greenhouse gas emissions. Decisions about how best to respond to climate change will require the input of economists in the analysis of the costs and benefits of the impacts of climate change against those of adaptation and mitigation.

The Intergovernmental Panel on Climate Change (IPCC) is the world's leading authority on the science of climate change and its impacts. One of the IPCC's roles is to produce periodic assessment reports providing an overview of current knowledge, as well as identifying uncertainties and gaps in knowledge. The IPCC Third Assessment Report (TAR) was published in 2001 and involved more than 2000 experts in its preparation. It remains the most authoritative published source of information on climate change. The Royal Society strongly urges the Stern Review to use the TAR as its primary source of scientific information. Scientific developments have been made since this report was published and while we refer to some of these in our submission, we strongly urge the Stern Review to consult with the Co-ordinating Lead Authors of the IPCC's Fourth Assessment Report which is currently being produced.

The remainder of this submission is arranged around the issues set out in the Stern Review's terms of reference. The findings of relevant Royal Society policy reports and statements are summarised, and questions which the Stern Review might usefully consider are raised. The Society would welcome the opportunity to engage further with the Stern Review as it progresses.

2 The implications for energy demand and emissions of the prospects for economic growth over the coming decades, including the composition and energy intensity of growth in developed and developing countries

There are significant resources of fossil fuels, conventional and unconventional, still remaining and it is considered likely that the world will go on consuming them for some considerable time. Many factors will mean that fossil fuels will probably remain the cheapest source of energy at least through the medium term. These include, *inter alia*:

- Many countries have large reserves of coal – an economically cheap and secure source of energy. The IEA projects that coal will still be the largest source of primary energy in both China and India by 2030 (IEA 2004). Approximately two thirds of the projected growth in global energy over the next 25 years will occur in developing countries.
- Many of the technologies used in the supply of fossil fuels are mature and therefore tend to incur lower development costs compared to technologies for renewable energy.
- End-use technologies tend to be optimised for the specific characteristics of fossil fuels – this is particularly relevant in the transport sector.
- Fossil fuels are a much denser source of energy than their renewable counterparts, which makes them much easier to 'harvest' and use (Smil, 2004).

While the low cost of fossil fuels mean it is likely that they will continue to be used until they are exhausted, the rate at which they are consumed, and consequently the rate at which greenhouse gases emitted, can have important implications for the stabilisation of greenhouse gas levels in the atmosphere. Failure to implement significant reductions in net greenhouse gas emissions now will make stabilisation much harder in the future.

3 The economic, social and environmental consequences of climate change in both developed and developing countries, taking into account the risks of increased climate volatility and major irreversible impacts, and the climatic interaction with other air pollutants, as well as possible actions to adapt to the changing climate and the costs associated with them;

In June 2005 the joint academies of the G8 nations along with those from China, India and Brazil published a statement on the science and impacts of climate change (Joint Academies 2005). They noted that increasing concentrations of greenhouse gases in the atmosphere have already caused the Earth's surface to warm by approximately 0.6 centigrade degrees over the twentieth century. They also drew attention to the fact that major parts of the climate system respond slowly to changes in greenhouse gas concentrations highlighting that further changes in climate are unavoidable, because even if greenhouse gas emissions were stabilised instantly at today's levels, the climate would still continue to change as it adapts to the increased emission of recent decades**.**

The IPCC's Third Assessment Report (IPCC, 2001) outlines many potential impacts which could result from increasing temperatures, for example: increased frequency and/or severity of weather events such as heat waves and heavy rainfall; severity of extreme events such as hurricane Katrina; and large-scale effects such as melting of large ice sheets (with major impacts on low-lying regions throughout the world). The Stern Review should consider how to isolate that portion of the human and economic costs resulting from these events for which climate change is responsible.

As noted above, the scientific understanding of climate change is now sufficiently clear to justify taking prompt action now. Significantly reducing the build up of greenhouse gases in the atmosphere will lessen the magnitude and rate of climate change. However, understanding a system as complex as the world's climate

is difficult. At present, this complexity means it is not possible to project with confidence the difference in impact between atmospheric CO_2 concentrations of 450, 550, 650 parts per million by volume (ppmv). However we do know that impacts will increase as concentration rises. It is also not possible to say with confidence if there is a threshold in the climate system above which the severity of the impacts increase rapidly, although in a nonlinear system such as the climate system one could expect to see a threshold. It is for this reason that the joint academies of the G8 nations, with China, India and Brazil called on world leaders to launch an international study, informed by science, to explore the targets for greenhouse gases concentrations, and their associated emissions scenarios, that will enable nations to avoid the impacts deemed unacceptable.

The Stern Review should consider the costs and benefits of seeking international agreement for a challenging yet attainable target, such as 550 ppmv atmospheric CO_2 concentration that would allow later adjustment of the target if necessary. The Stern Review should also consider the implications of a delay in establishing the target.

Evaluation of the impacts of climate change needs also to consider regional and local impacts. The projected changes in climate will have both beneficial and adverse effects at the regional level, for example on water resources, agriculture, natural ecosystems and human health. The larger and faster the changes in climate, the more likely it is that adverse effects will dominate (Joint Academies 2005). The economic modelling should also recognise that although the general trends for future climate change are clear, important geographical patterns of climate change and the magnitudes of, for example local warming, are much less certain. In addition, not all climate change is well described by simple unidirectional shifts in conditions. For example, global warming means (to a first approximation) that wet areas get wetter, and dry areas get drier, but does not show the geographical shifts of areas of high and low precipitation and changes in rainfall patterns. Such effects also lead to redistribution and abundance of plants and animals. These are poorly described by simple aggregate measures (e.g. of total plant production).

The Stern Review should also consider the potential impact of climate change on food crops, particularly in most vulnerable areas such as Africa. The report of the Royal Society Discussion Meeting on Food crops in a changing climate (Royal Society, 2005a) highlights some of the likely impacts of climate change on agriculture and food security. There is increasing information on the importance of extremes of temperature and rainfall at key stage of crop development on crop yield. Recent advances in understanding of crop physiology indicate that crop yield and quality may be more severely adversely affected by climate change than previously thought. Crops and other vegetation can also interact with the climate system to affect regional rainfall.

3.1 Adaptation

Developing nations that lack the infrastructure or resources to respond to the impacts of climate change will be particularly affected by it. It is clear that many of the world's poorest people are likely to suffer the most from climate change. Long-term global efforts to create a more healthy, prosperous and sustainable world may be severely hindered by changes in the climate (Joint Academies 2005). The Stern Review should also consider the implications of the possible risk that the climate may change more rapidly than the adjustment time of human society.

Developing strategies for adapting to climate change will depend critically on results from climate-model predictions. These will provide the basis for detailed decisions regarding infrastructure investment in the light of anticipated climate change on a local level, for example investment in new reservoirs and flood defences. The task of devising and implementing strategies to adapt to the consequences of climate change will require worldwide collaborative inputs from a wide range of experts, including physical and natural scientists, engineers, social scientists, medical scientists, those in the humanities, business leaders and economists (Joint

Academies 2005). Better integration of the models used by economists with those used by social and natural scientists should form an important part of this collaboration – any guidance the Stern Review is able to provide on how this could be achieved would be very useful.

3.2 Ocean acidification

In addition to the effect on the climate system, anthropogenic carbon dioxide emissions have also been significantly increasing the acidity of the world's oceans. This was the subject of a report for the Society, released earlier this year *Ocean acidification due to increasing atmospheric carbon dioxide* (Royal Society, 2005b)

Calculations based on measurements of the surface oceans and our knowledge of ocean chemistry indicate that uptake of carbon dioxide by the world's oceans has already led to a reduction of the pH of surface seawater by around 0.1 units – equivalent to a 30 percent increase in the concentration of hydrogen ions. The magnitude of ocean acidification can be predicted with a high level of confidence. If current emission trends continue, by 2100 pH levels could fall to a level which would probably be lower than has been experienced for hundreds of millennia and, critically, the rate of change is probably one hundred times greater than at any time over this period. The likely affects of this increase in acidity are poorly understood; however, there is convincing evidence that there could be significant negative impacts on marine ecosystems, particularly for coral reefs and for calcifying organisms in the Southern Ocean. Ocean acidification is also likely to have significant effects on some marine fisheries and shell fish species.

The socio-economic effects of ocean acidification are hard to determine but could amount to many billions of dollars. Reducing carbon dioxide emissions to the atmosphere appear to be the only practical way to minimise the risk of large-scale and long-term changes to the oceans. The costs of the potential impacts of ocean acidification should therefore be included in the shadow price of carbon.

4 The costs and benefits of actions to reduce the net global balance of greenhouse gas emissions from energy use and other sources, including the role of land-use changes and forestry, taking into account the potential impact of technological advances on future costs;

The scale of the problem to be addressed requires that all options for reducing greenhouse gas emissions should be open to consideration, including using less energy, using fuels which emit fewer or no greenhouse gases (such as generation of electricity from renewable or nuclear sources) and preventing those gases from reaching the atmosphere. (Royal Society and Royal Academy of Engineering, 1999; Royal Society, 2002).

Preventing greenhouse gases from reaching the atmosphere, using carbon capture and storage (CCS), is a concept which has recently gained in currency – including the current Inquiry by the House of Commons Science and Technology Select Committee. The Royal Society's submission to this Inquiry is expected to be available soon. CCS involves the collection of carbon dioxide from large scale energy and industrial sources and storage – for example in geological formations[1]. Current research (summarised in IPCC, 2005) suggests that between 80 and 90 percent of CO_2 emissions from a technically suitable source, such as a large power plant designed to have a CCS system retrofitted, could be captured and stored for at least a thousand years and possibly up to a million years. By 2050 it is anticipated that between 20 and 40 percent of global CO_2 emissions could be technically suitable for CCS. Estimating the total amount of CO_2 which could be stored

[1] Storage in the deep ocean or via fixation into organic carbonates are also options. The potential adverse effects from ocean acidification mean that storage in the deep ocean should not be considered as an option. Research into fixation of carbon into organic carbonates is currently at a very early stage.

underground is made difficult by the lack of information on availability of appropriate geological formations – particularly in developing countries. Furthermore, the proximity of future large sources of CO_2 (e.g. power stations) to potential storage sites has not been studied. There is also debate about the costs of CCS. However, modelling based on the IPCC cost assumptions suggests that significant deployment of CCS could occur if CO_2 was priced at around US$ 25-30 per tonne of carbon dioxide via an emissions trading scheme or carbon tax.

While some people have suggested that land carbon sinks (soil and vegetation that have been managed to increase their uptake and storage of CO_2) the may be a useful CO_2 abatement option a Royal Society report (Royal Society, 2001) found that considerable uncertainty remains in the scientific understanding of the causes, magnitude and permanence of the land carbon sink. Furthermore, the potential to enhance the land carbon sink through changes in land management practices is finite in size and duration. The report concluded that projects designed to enhance land carbon sinks must not, therefore, be allowed to divert financial and political resources away from the restructuring of energy generation and use, technological innovation (e.g. increased fuel efficiency, sequestration of CO_2 at source) and technology transfer to less developed countries.

We believe the Stern Review should consider the following issues:

- Being able to deliver the technological developments necessary to meet the challenges posed by climate change will require investment in building scientific and technical capacity. How this investment will be delivered should be considered.
- The benefits of current UK greenhouse gas abatement policies will only be accrued if a 'credible' group of countries agree to stabilise atmospheric concentration of greenhouse gases at a defined level (i.e. a group of countries that will actually be able to affect a reduction in greenhouse gas emissions sufficient to achieve the desired level of stabilisation). What are the implications of this situation for the evaluation of a policy's cost effectiveness? Should the definition of a the benefits of a given policy include its contribution to achieving sufficient international buy-in and its ability to enhance the chances of success of that international effort?
- How can economic analysis best deal with the long time scales of climate change? Standard techniques used by economists to evaluate future costs and benefits in present day terms (for example, exponential discounting) make the impacts of climate change beyond a few decades almost irrelevant.
- Economic models usually assume steady, smooth growth in GDP. The Stern Review should consider the validity of these assumptions, given what the science tells us about the likely impacts of climate change, in particular, the inclusion of potential climate change shocks.
- Evaluating the impacts of climate change involves multiple criteria (human, economic, environmental etc) many of which cannot usefully be reduced to simple monetary units which would enable straightforward cost benefit analysis. Is there a role, therefore, for multi-criteria decision analysis (which maintains the emphasis on quantification of impacts but does not require conversion to monetary units) in the evaluation of the costs and benefits of climate change?
- How policies to promote security of supply interact with policies to reduce greenhouse gas emission from the energy sector.

5 The impact and effectiveness of national and international policies and arrangements in reducing net emissions in a cost-effective way and promoting a dynamic, equitable and sustainable global economy, including distributional effects and impacts on incentives for investment in cleaner technologies.

A recent Society report '*Economic instruments for the reduction of carbon dioxide emissions*' (Royal Society, 2002) strongly advocates that the primary emphasis of climate change policy should be on the introduction

of an economic instrument, such as a universal carbon tax or auctioned permits, which places a penalty on all greenhouse gas emissions, irrespective of source. Ideally the form of the instrument should be the simplest that can be devised, so that it is comprehensible to all stakeholders, and (equally importantly) so that it facilitates international agreements. There may also be a need for government to apply regulation alongside an economic instrument, and there will always be an important role for advocacy and education. The conclusions of this report included, *inter alia*:

Cost-effectiveness

- Controlling emission of greenhouse gases can be affected at lower overall cost by the application of an economic instrument than by a system based on regulation.
- Because an effective carbon tax or permit auction is likely to raise considerable revenues, any analysis should also consider the recycling of revenues by different means, for example, by reducing taxes on employment or the gradual replacement of value-added tax.
- Several different studies have found that, with efficient revenue recycling, the overall cost of even a very significant reduction in greenhouse gas emissions is modest, with estimates in the range of 1% of long-term global GDP.
- Higher prices of carbon also give a price incentive to help prevent rebound effects[2] from energy efficiency improvements, which are a substantial component of the UK's climate-change programme.
- Finally an escalating, expected, rate of tax or permit price, will reduce costs of mitigation by encouraging fossil-fuel users and energy investors to anticipate higher future costs, as an "announcement effect", and encourage a shift to new long-lived capital associated with a low-carbon economy.

Impacts on equity[3]

- Universal application of an economic instrument will require the Government to introduce or extend measures to avoid penalising the more vulnerable members of the community. They should be compensated but not shielded from its impact.
- Any measure to shield carbon-intensive industries from the impact of an economic instrument should be time-limited and transparent in the form of explicit subsidies. The intention is to make carbon-intensive products less competitive.

Incentives for cleaner technology

- An economic instrument creates a clear incentive for the market to innovate new low-carbon technologies.

Internationalisation

- An economic instrument should be introduced in a phased way and with the aim of eventual convergence with the nations of the EU, and beyond. The vital first step is to seek and reach an understanding *in principle* – that emission control would in future be based on the application of a carbon tax or related economic instrument. Reaching an agreement on as wide an international basis as possible is more important than the speed with which a fully-fledged scheme is implemented. It is not inevitable that countries must adopt the remedies at the same rate, but it is essential that there is agreement to converge to a solution.

We believe the Stern Review should consider:

- To what extent could the potential costs of mitigation and adaptation be offset by taking advantage of the commercial opportunities that these activities offer?

[2] The rebound or take back effect, is the extent to which the cost saving produced by an investment in energy efficiency is taken back by consumers in the form of higher energy consumption.
[3] The study did not review the impacts on equity at an international level.

- What would be the optimal grouping of sectors to include in the European Union Emissions Trading Scheme beyond 2008? How could its geographical coverage be consolidated, in particular to include developing countries such as China and India?
- Can experience in other areas of industrial policy inform the debate surrounding the role of government in innovation investment for climate change?

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