STERN REVIEW: The Economics of Climate Change

**Preface**

This Review was announced by the Chancellor of the Exchequer in July 2005. The

Review set out to provide a report to the Prime Minister and Chancellor by Autumn 2006

assessing:

• the economics of moving to a low-carbon global economy, focusing on the

medium to long-term perspective, and drawing implications for the timescales for

action, and the choice of policies and institutions;

• the potential of different approaches for adaptation to changes in the climate; and

• specific lessons for the UK, in the context of its existing climate change goals.

The terms of reference for the Review included a requirement to consult broadly with

stakeholders and to examine the evidence on:

• 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;

• 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;

• 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; and

• 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.

**Overall approach to the Review**

We have taken a broad view of the economics required to understand the challenges of climate change. Wherever possible, we have based our Review on gathering and structuring existing research material...

**Introduction**

The economics of climate change is shaped by the science. That is what dictates the structure of the economic analysis and policies; therefore we start with the science.

Human-induced climate change is caused by the emissions of carbon dioxide and

other greenhouse gases (GHGs) that have accumulated in the atmosphere mainly

over the past 100 years.

The scientific evidence that climate change is a serious and urgent issue is now

compelling. It warrants strong action to reduce greenhouse gas emissions around the

world to reduce the risk of very damaging and potentially irreversible impacts on

ecosystems, societies and economies. With good policies the costs of action need

not be prohibitive and would be much smaller than the damage averted.

Reversing the trend to higher global temperatures requires an urgent, world-wide

shift towards a low-carbon economy. Delay makes the problem much more difficult

and action to deal with it much more costly. Managing that transition effectively and

efficiently poses ethical and economic challenges, but also opportunities, which this

Review sets out to explore.

Economics has much to say about assessing and managing the risks of climate

change, and about how to design national and international responses for both the

reduction of emissions and adaptation to the impacts that we can no longer avoid. If

economics is used to design cost-effective policies, then taking action to tackle

climate change will enable societies’ potential for well-being to increase much faster

in the long run than without action; we can be ‘green’ and grow. Indeed, if we are not

‘green’, we will eventually undermine growth, however measured.

This Review takes an international perspective on the economics of climate change.

Climate change is a global issue that requires a global response. The science tells

us that emissions have the same effects from wherever they arise. The implication

for the economics is that this is clearly and unambiguously an international collective

action problem with all the attendant difficulties of generating coherent action and of

avoiding free riding. It is a problem requiring international cooperation and

leadership.

Our approach emphasises a number of key themes, which will feature throughout.

• We use a consistent approach towards uncertainty. The science of climate

change is reliable, and the direction is clear. But we do not know precisely

when and where particular impacts will occur. Uncertainty about impacts

strengthens the argument for mitigation: this Review is about the economics

of the management of very large risks.

• We focus on a quantitative understanding of risk, assisted by recent

advances in the science that have begun to assign probabilities to the

relationships between emissions and changes in the climate system, and to

those between the climate and the natural environment.

• We take a systematic approach to the treatment of inter- and intragenerational

equity in our analysis, informed by a consideration of what

various ethical perspectives imply in the context of climate change. Inaction

now risks great damage to the prospects of future generations, and

particularly to the poorest amongst them. A coherent economic analysis of

policy requires that we be explicit about the effects.

Economists describe human-induced climate change as an ‘externality’ and the

global climate as a ‘public good’. Those who create greenhouse gas emissions as

they generate electricity, power their factories, flare off gases, cut down forests, fly in

planes, heat their homes or drive their cars do not have to pay for the costs of the

climate change that results from their contribution to the accumulation of those gases

in the atmosphere.

But climate change has a number of features that together distinguish it from other

externalities. It is global in its causes and consequences; the impacts of climate

change are persistent and develop over the long run; there are uncertainties that

prevent precise quantification of the economic impacts; and there is a serious risk of

major, irreversible change with non-marginal economic effects.

This analysis leads us to five sets of questions that shape Parts 2 to 6 of the Review.

• What is our understanding of the risks of the impacts of climate change, their

costs, and on whom they fall?

• What are the options for reducing greenhouse-gas emissions, and what do

they cost? What does this mean for the economics of the choice of paths to

stabilisation for the world? What are the economic opportunities generated

by action on reducing emissions and adopting new technologies?

• For mitigation of climate change, what kind of incentive structures and

policies will be most effective, efficient and equitable? What are the

implications for the public finances?

• For adaptation, what approaches are appropriate and how should they be

financed?

• How can approaches to both mitigation and adaptation work at an

international level?

**Summary of Conclusions**

There is still time to avoid the worst impacts of climate change, if we take

strong action now.

The scientific evidence is now overwhelming: climate change is a serious global

threat, and it demands an urgent global response.

This Review has assessed a wide range of evidence on the impacts of climate

change and on the economic costs, and has used a number of different techniques to

assess costs and risks. From all of these perspectives, the evidence gathered by the

Review leads to a simple conclusion: the benefits of strong and early action far

outweigh the economic costs of not acting.

Climate change will affect the basic elements of life for people around the world –

access to water, food production, health, and the environment. Hundreds of millions

of people could suffer hunger, water shortages and coastal flooding as the world

warms.

Using the results from formal economic models, the Review estimates that if we don’t

act, the overall costs and risks of climate change will be equivalent to losing at least

5% of global GDP each year, now and forever. If a wider range of risks and impacts

is taken into account, the estimates of damage could rise to 20% of GDP or more.

In contrast, the costs of action – reducing greenhouse gas emissions to avoid the

worst impacts of climate change – can be limited to around 1% of global GDP each

year.

The investment that takes place in the next 10-20 years will have a profound effect

on the climate in the second half of this century and in the next. Our actions now and

over the coming decades could create risks of major disruption to economic and

social activity, on a scale similar to those associated with the great wars and the

economic depression of the first half of the 20th century. And it will be difficult or

impossible to reverse these changes.

So prompt and strong action is clearly warranted. Because climate change is a

global problem, the response to it must be international. It must be based on a

shared vision of long-term goals and agreement on frameworks that will accelerate

action over the next decade, and it must build on mutually reinforcing approaches at

national, regional and international level.

Climate change could have very serious impacts on growth and development.

If no action is taken to reduce emissions, the concentration of greenhouse gases in

the atmosphere could reach double its pre-industrial level as early as 2035, virtually

committing us to a global average temperature rise of over 2°C. In the longer term,

there would be more than a 50% chance that the temperature rise would exceed

5°C. This rise would be very dangerous indeed; it is equivalent to the change in

average temperatures from the last ice age to today. Such a radical change in the

physical geography of the world must lead to major changes in the human geography

* where people live and how they live their lives.

Even at more moderate levels of warming, all the evidence – from detailed studies of

regional and sectoral impacts of changing weather patterns through to economic

models of the global effects – shows that climate change will have serious impacts

on world output, on human life and on the environment.

All countries will be affected. The most vulnerable – the poorest countries and

populations – will suffer earliest and most, even though they have contributed least to

the causes of climate change. The costs of extreme weather, including floods,

droughts and storms, are already rising, including for rich countries.

Adaptation to climate change – that is, taking steps to build resilience and minimise

costs – is essential. It is no longer possible to prevent the climate change that will

take place over the next two to three decades, but it is still possible to protect our

societies and economies from its impacts to some extent – for example, by providing

better information, improved planning and more climate-resilient crops and

infrastructure. Adaptation will cost tens of billions of dollars a year in developing

countries alone, and will put still further pressure on already scarce resources.

Adaptation efforts, particularly in developing countries, should be accelerated.

The costs of stabilising the climate are significant but manageable; delay

would be dangerous and much more costly.

The risks of the worst impacts of climate change can be substantially reduced if

greenhouse gas levels in the atmosphere can be stabilised between 450 and

550ppm CO2 equivalent (CO2e). The current level is 430ppm CO2e today, and it is

rising at more than 2ppm each year. Stabilisation in this range would require

emissions to be at least 25% below current levels by 2050, and perhaps much more.

Ultimately, stabilisation – at whatever level – requires that annual emissions be

brought down to more than 80% below current levels.

This is a major challenge, but sustained long-term action can achieve it at costs that

are low in comparison to the risks of inaction. Central estimates of the annual costs

of achieving stabilisation between 500 and 550ppm CO2e are around 1% of global

GDP, if we start to take strong action now.

Costs could be even lower than that if there are major gains in efficiency, or if the

strong co-benefits, for example from reduced air pollution, are measured. Costs will

be higher if innovation in low-carbon technologies is slower than expected, or if

policy-makers fail to make the most of economic instruments that allow emissions to

be reduced whenever, wherever and however it is cheapest to do so.

It would already be very difficult and costly to aim to stabilise at 450ppm CO2e. If we

delay, the opportunity to stabilise at 500-550ppm CO2e may slip away.

Action on climate change is required across all countries, and it need not cap

the aspirations for growth of rich or poor countries.

The costs of taking action are not evenly distributed across sectors or around the

world. Even if the rich world takes on responsibility for absolute cuts in emissions of

60-80% by 2050, developing countries must take significant action too. But

developing countries should not be required to bear the full costs of this action alone,

and they will not have to. Carbon markets in rich countries are already beginning to

deliver flows of finance to support low-carbon development, including through the

Clean Development Mechanism. A transformation of these flows is now required to

support action on the scale required.

Action on climate change will also create significant business opportunities, as new

markets are created in low-carbon energy technologies and other low-carbon goods

and services. These markets could grow to be worth hundreds of billions of dollars

each year, and employment in these sectors will expand accordingly.

The world does not need to choose between averting climate change and promoting

growth and development. Changes in energy technologies and in the structure of

economies have created opportunities to decouple growth from greenhouse gas

emissions. Indeed, ignoring climate change will eventually damage economic growth.

Tackling climate change is the pro-growth strategy for the longer term, and it can be

done in a way that does not cap the aspirations for growth of rich or poor countries.

A range of options exists to cut emissions; strong, deliberate policy action is

required to motivate their take-up.

Emissions can be cut through increased energy efficiency, changes in demand, and

through adoption of clean power, heat and transport technologies. The power sector

around the world would need to be at least 60% decarbonised by 2050 for

atmospheric concentrations to stabilise at or below 550ppm CO2e, and deep

emissions cuts will also be required in the transport sector.

Even with very strong expansion of the use of renewable energy and other lowcarbon

energy sources, fossil fuels could still make up over half of global energy

supply in 2050. Coal will continue to be important in the energy mix around the

world, including in fast-growing economies. Extensive carbon capture and storage

will be necessary to allow the continued use of fossil fuels without damage to the

atmosphere.

Cuts in non-energy emissions, such as those resulting from deforestation and from

agricultural and industrial processes, are also essential.

With strong, deliberate policy choices, it is possible to reduce emissions in both

developed and developing economies on the scale necessary for stabilisation in the

required range while continuing to grow.

Climate change is the greatest market failure the world has ever seen, and it

interacts with other market imperfections. Three elements of policy are required for

an effective global response. The first is the pricing of carbon, implemented through

tax, trading or regulation. The second is policy to support innovation and the

deployment of low-carbon technologies. And the third is action to remove barriers to

energy efficiency, and to inform, educate and persuade individuals about what they

can do to respond to climate change.

Climate change demands an international response, based on a shared

understanding of long-term goals and agreement on frameworks for action.

Many countries and regions are taking action already: the EU, California and China

are among those with the most ambitious policies that will reduce greenhouse gas

emissions. The UN Framework Convention on Climate Change and the Kyoto

Protocol provide a basis for international co-operation, along with a range of

partnerships and other approaches. But more ambitious action is now required

around the world.

Countries facing diverse circumstances will use different approaches to make their

contribution to tackling climate change. But action by individual countries is not

enough. Each country, however large, is just a part of the problem. It is essential to

create a shared international vision of long-term goals, and to build the international

frameworks that will help each country to play its part in meeting these common

goals.

Key elements of future international frameworks should include:

• Emissions trading: Expanding and linking the growing number of emissions

trading schemes around the world is a powerful way to promote cost-effective

reductions in emissions and to bring forward action in developing countries:

strong targets in rich countries could drive flows amounting to tens of billions of

dollars each year to support the transition to low-carbon development paths.

• Technology cooperation: Informal co-ordination as well as formal agreements can

boost the effectiveness of investments in innovation around the world. Globally,

support for energy R&D should at least double, and support for the deployment of

new low-carbon technologies should increase up to five-fold. International cooperation on product standards is a powerful way to boost energy efficiency.

• Action to reduce deforestation: The loss of natural forests around the world

contributes more to global emissions each year than the transport sector.

Curbing deforestation is a highly cost-effective way to reduce emissions; largescale

international pilot programmes to explore the best ways to do this could get

underway very quickly.

• Adaptation: The poorest countries are most vulnerable to climate change. It is

essential that climate change be fully integrated into development policy, and that

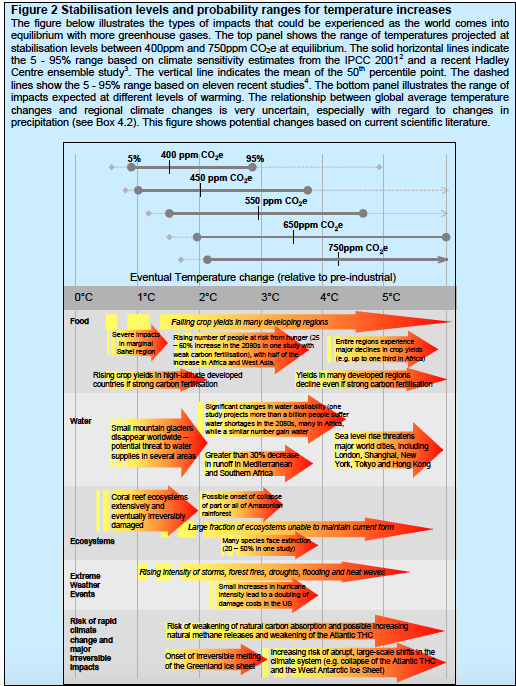
rich countries honour their pledges to increase support through overseas

development assistance. International funding should also support improved

regional information on climate change impacts, and research into new crop

varieties that will be more resilient to drought and flood.

I PASTE INTERESTING GRAPHS FROM THE REPORT BELOW



**Figure 1 Greenhouse-gas emissions in 2000, by source**

**ENERGY**

**EMISSIONS**

Power (24%)

Industry (14%)

Other energy related (5%)

Waste (3%)

Transport

(14%)

Buildings (8%)

Agriculture

(14%)

**NON-ENERGY EMISSIONS**

Total emissions in 2000: 42 GtCO2e.

Land use

(18%)

Energy emissions are mostly CO2 (some non-CO2 in industry and other energy related). Non-energy emissions are CO2 (land use) and non-CO2 (agriculture and waste).

**Source:** Prepared by Stern Review, from data drawn from World Resources Institute Climate Analysis Indicators Tool (CAIT) on-line database version 3.0.