The John Ray Initiative
Connecting environment, science and Christianity
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Global Warming, Climate Change and Sustainability

Challenge to Scientists, Policy Makers and Christians

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In this paper, I first list some of the growing threats to the environment and introduce the important concept of sustainability. I then explain the threat arising from human induced climate change, summarising its scientific basis and the most significant impacts. I proceed to outline the action that is necessary to halt climate change especially in the energy sector. Finally, I emphasise the moral imperative for action and suggest how Christians in particular should respond to the challenge.

Why care for the Environment?

It has always been important to look after our local environment if only so that we can pass on to our children and grandchildren an environment at least as good as we have enjoyed. Today, however, it is not just the local environment that is at risk but the global environment. Small amounts of pollution for which each of us is responsible are affecting everyone in the world. For instance, very small quantities of chlorofluorocarbons (CFCs) emitted to the atmosphere from leaking refrigerators or some industrial processes have resulted in degradation of the ozone layer and carbon dioxide that enters the atmosphere from the burning of fossil fuels, coal, oil and gas is leading to damaging climate change. Pressures from rapidly increasing world population and from increasing overuse of the earth's resources are making such problems much more acute and exacerbating the damage both to ecosystems and to human communities. The perils of human induced climate change are now recognised much more widely. It is frequently described by responsible scientists and politicians as probably 'the greatest problem the world faces' and as a 'weapon of mass destruction'. Global pollution demands global solutions.

To arrive at global solutions it is necessary to address human attitudes very broadly, for instance those concerned with resource use, lifestyle, wealth and poverty. They must also involve human society at all levels of aggregation - international organisations, nations with their national and local governments, large and small industry and businesses, non-governmental organisations (e.g. churches) and individuals. To take into account the breadth of concern, a modern term that is employed to describe such environmental care is 'sustainability'.

What is Sustainability?

Imagine you are a member of the crew of a large space ship on a voyage to visit a distant planet. Your journey there and back will take many years. An adequate, high quality source of energy is readily available in the radiation from the sun. Otherwise, resources for the journey are limited. The crew on the spacecraft are engaged for much of the time in managing the resources as carefully as possible. A local biosphere is created in the spacecraft where plants are grown for food and everything is recycled. Careful accounts are kept of all resources, with especial emphasis on non-replaceable components. That the resources be sustainable at least for the duration of the voyage, both there and back, is clearly essential.

Planet Earth is enormously larger than the spaceship I have just been describing. The crew of Spaceship Earth at six billion and rising is also enormously larger. The principle of Sustainability should be applied to Spaceship Earth as rigorously as it has to be applied to the much smaller vehicle on its interplanetary journey. In a publication in 1966, Professor Kenneth Boulding, a distinguished American economist, employed the image of Spaceship Earth. He contrasted an 'open' or 'cowboy' economy (as he called an unconstrained economy) with a 'spaceship' economy in which sustainability is paramount[1].

Sustainability is an idea that can be applied to activities and communities as well as to physical resources. Environmental sustainability is strongly linked to social sustainability - about sustainable communities - and sustainable economics. Sustainable Development provides an all-embracing term. The Brundtland Report, "Our Common Future" of 1987 provides a milestone review of Sustainable Development issues.

There have been many definitions of Sustainability. The simplest I know is 'not cheating on our children'; to that may be added, 'not cheating on our neighbours' and 'not cheating on the rest of creation'. In other words, not passing on to our children or any future generation, an Earth that is degraded compared to the one we inherited, and also sharing common resources as necessary with our neighbours in the rest of the world and caring properly for the non-human creation.

Crisis of Sustainability

The human activities of an increasing world population together with the accompanying rapid industrial development, are leading to degradation of the

[1] Kenneth Boulding was Professor of Economics at the University of Colorado, sometime President of the American Economics Association and of the American Association for the Advancement of Science. His article, 'The Economics of the Coming Spaceship Earth' was published in 1966 in 'Environmental Quality in a Growing Economy' pp 77-82.

environment on a very large scale. Notwithstanding, some deny that degradation is happening; others that degradation matters. Scientists have an important role in ensuring the availability of accurate information about degradation and also in pointing to how humans can begin to solve the problems.

Many things are happening in our modern world that are just not sustainable[2]. In fact, we are all guilty of cheating in the three respects I have mentioned. The table below lists five of the most important issues, briefly showing how they are all connected together and also linked to other major areas of human activity or concern. To illustrate these connections let me use the example of deforestation. Every year tropical forest is cut down or burnt equivalent approximately to the area of the island of Ireland. Some is to harvest valuable hardwoods unsustainably; some is to raise cattle to provide beef for some of the world's richest countries. This level of deforestation adds significantly to the atmospheric greenhouse gases carbon dioxide and methane so increasing the rate of human induced climate change. It is also likely to change the local climate close to the region where the deforestation is occurring. For instance, in the Amazon if current levels of deforestation continue, some of Amazonia could become much drier, even semi-desert, during this century. Further, when the trees go, soil is lost by erosion; again in many parts of Amazonia the soil is poor and easily washed away. Tropical forests are also rich in biodiversity. With loss of forests there will be much irreplaceable biodiversity loss.

TABLE

Important Sustainability Issues

Issue	Links
Global Warming & Climate Change	Energy, Transport, Biodiversity Loss, Deforestation Water, Soil loss, Agriculture, Food
Land Use Change	Biodiversity Loss, Deforestation, Water, Soil loss, Climate Change, Agriculture, Food
Consumption	Biodiversity Loss, Deforestation, Water, Soil loss, Climate Change, Agriculture, Food
Waste	Consumption, Energy, Agriculture, Food
Fish	Consumption, Food

[2] See, for instance, UNEP, '*Global Environmental Outlook 3'*,pp 446, Earthscan Publications, London 2002

All these issues present enormous challenges. For much of the rest of this paper I will address in some detail the world's most serious environmental and sustainability issue - one with which I have been particularly concerned - that of global warming and climate change, explaining the essential roles of both science and faith in getting to grips with it.

Global Warming and Climate Change: the Basic Science

I begin with a quick summary of the basic science. By absorbing infra-red or 'heat' radiation from the earth's surface, 'greenhouse gases' present in the atmosphere, such as water vapour and carbon dioxide, act as blankets over the earth's surface, keeping it on average 20 or 30ºC warmer than it would otherwise be. The existence of this natural 'greenhouse effect' has been known for nearly two hundred years; it is essential to the provision of our current climate to which ecosystems and we humans have adapted.

A record of past climate and atmospheric composition is provided from analyses of the composition of the ice and air bubbles trapped in the ice obtained from different depths from cores drilled into the Antarctic or Greenland ice caps (Fig 1). From such records we find that, since the beginning of the industrial revolution around 1750, one of the greenhouse gases, carbon dioxide has increased by nearly 40% and is now at a higher concentration in the atmosphere than it has been probably for millions of years. Chemical analysis demonstrates that this increase is due largely to the burning of fossil fuels - coal, oil and gas. If no action is taken to curb these emissions, the carbon dioxide concentration will rise during the 21st century to two or three times its preindustrial level.

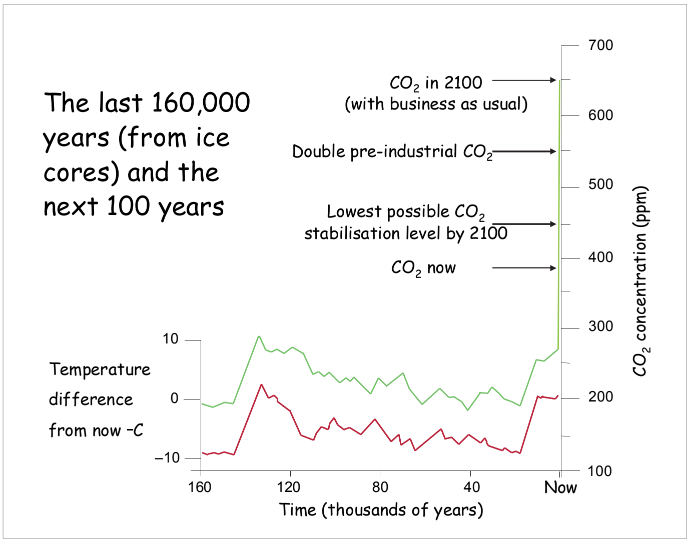


Fig 1 Changes of atmospheric temperature and carbon dioxide concentration in the atmosphere during the last ice age as shown from the 'Vostok' ice core drilled from Antarctica. The main triggers for ice ages have been small regular variations in the geometry of the Earth's orbit about the sun. The next ice age is predicted to begin to occur in about 50,000 years time.

The climate record over the last 1000 years (Fig 2) shows a lot of natural variability – including, for instance, the 'medieval warm period' and the 'little ice age'. The rise in global average temperature (and its rate of rise) during the 20th century (Fig 2a) is well outside the range of known natural variability. The year 1998 is the warmest year in the instrumental record. A more striking statistic is that each of the first 8 months of 1998 was the warmest on record for that month. There is strong evidence that most of the warming over the last 50 years is due to the increase of greenhouse gases, especially carbon dioxide. Confirmation of this is also provided by observations of the warming of the oceans. The period of 'global dimming' from about 1950 to 1970 is most likely due to the increase in atmospheric particles (especially sulphates) from industrial sources. These particles reflect sunlight, hence tending to cool the surface and mask some of the warming effect of greenhouse gases.

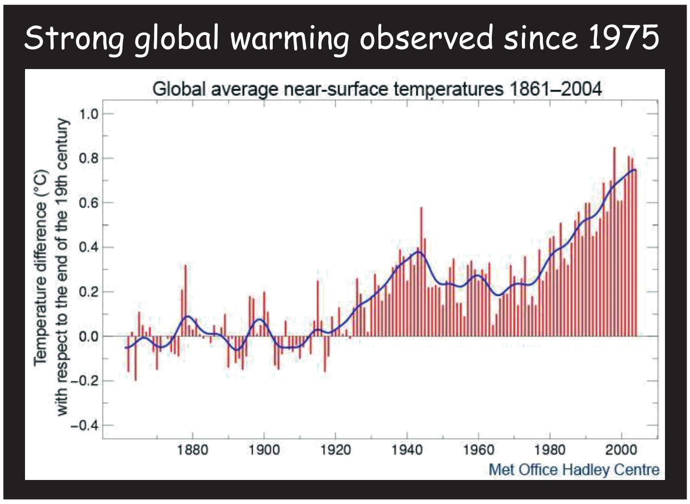
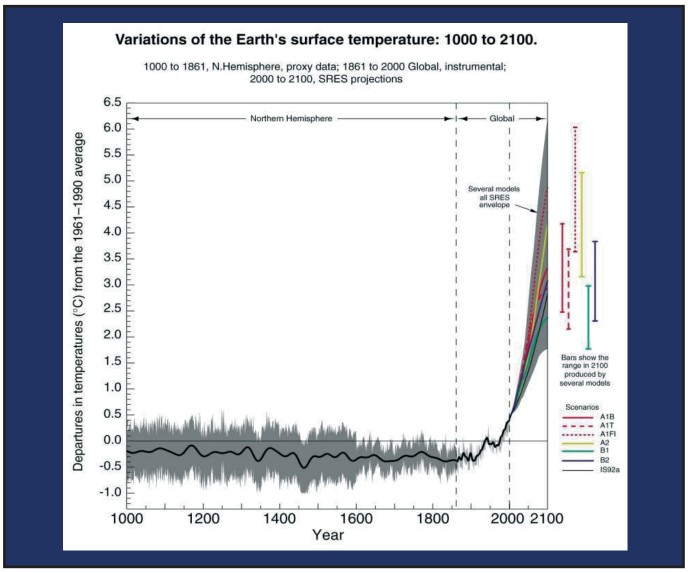


Fig 2 (a & b) Variations of the average near-surface air temperature. (a) global instrumental from 1861-2004;



(b) 1000-1860, N Hemisphere from proxy data; 1861-2000, global instrumental; 2000-2100 under a range of IPCC projections with further shading to indicate scientific uncertainty[3].

Over the 21st century the global average temperature is projected to rise by between 2 and 6 ºC (3.5 to 11 ºF) from its preindustrial level; the range represents different assumptions about emissions of greenhouse gases and the sensitivity of the climate model used in making the estimate (Fig 2b). For global average temperature, a rise of this amount is large. Its difference between the middle of an ice age and the warm periods in between is only about 5 or 6 ºC (9 to 11 ºF)[4]. So, associated with likely warming in the 21st century will be a rate of change of climate equivalent to say, half an ice age in less than 100 years – a larger rate of change than for at least 10,000 years. Adapting to this will be difficult for both humans and many ecosystems.

The impacts of climate change

Talking in terms of changes of global average temperature, however, tells us rather little about the impacts of global warming on human communities. Some of the most obvious impacts will be due to the rise in sea level that occurs because ocean water expands as it is heated. The projected rise is of the order of half a metre a century and will continue for many centuries – to warm the deep oceans as well as the surface waters takes a long time. This will cause large problems for human communities living in low lying regions. Sea defences in many parts of the UK, for instance in the eastern counties of England, will need to be improved at substantial cost. However, many areas in other parts of the world, for instance in Bangladesh (where about 10 million live within the one metre contour – Fig 3), southern China, islands in the Indian and Pacific oceans and similar places elsewhere in the world will be impossible to protect and many millions will be displaced.

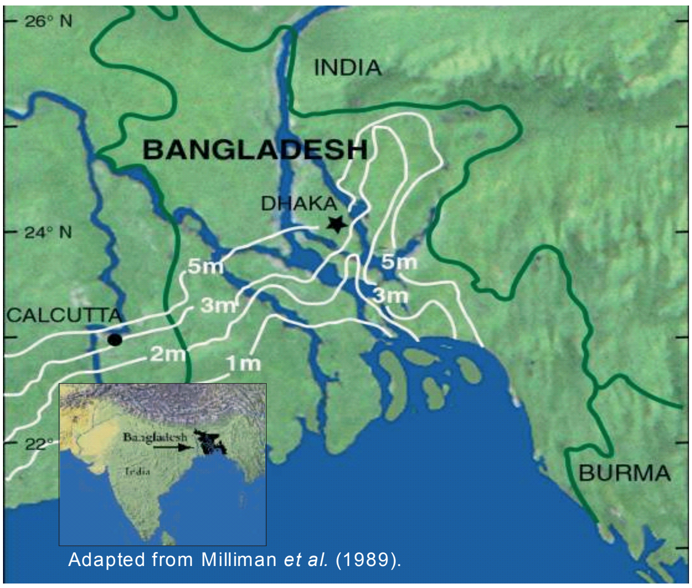


Fig 3 Land affected in Bangladesh by various amounts of sea level rise.

3 From IPCC 2001 Synthesis Report published by Cambridge University Press 2001.

4 See Fig 1, noting that changes in global average temperature are about half those at the poles.

There will also be impacts from extreme events. The extremely unusual high temperatures in central Europe during the summer of 2003 (Fig 4) led to the deaths of over 20,000 people. Careful analysis leads to the projection that such summers are likely to be average by the middle of the 21st century and cool by the year 2100.

Water is becoming an increasingly important resource. A warmer world will lead to more evaporation of water from the surface, more water vapour in the atmosphere and more precipitation on average. Of greater importance is the fact that the increased condensation of water vapour in cloud formation leads to increased latent heat of condensation being released. Since this latent heat release is the largest source of energy driving the atmosphere's circulation, the hydrological cycle will become more intense. This means a tendency to more intense rainfall events and also less rainfall in some semi-arid areas.

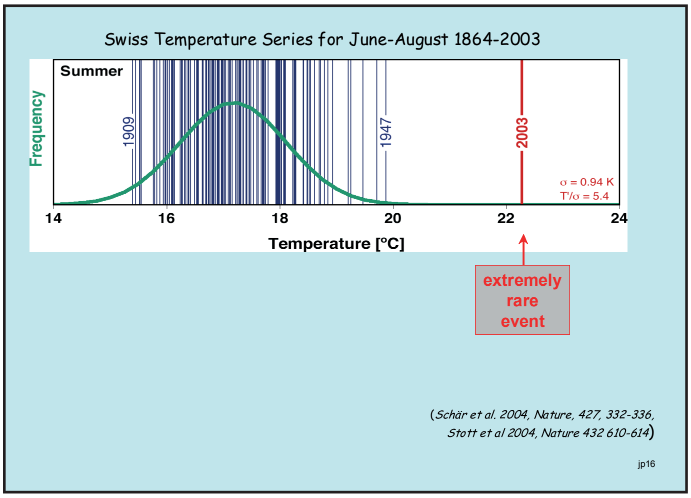


Fig 4 Distribution of average summer temperatures (June, July and August) in Switzerland from 1864-2003 showing a fitted gaussian probability distribution[5]. The 2003 value is 5.4 standard deviations from the mean showing it as an extremely rare event far outside the normal range of climatic variability.

On average, floods and droughts are the most damaging of the world's disasters. Between 1975 and 2002, due to flooding from rainfall over 200,000 lives were lost and 2.2 billion affected and due to drought over half a million lives were lost and 1.3 billion affected[6]. Their greater frequency and intensity is bad news for most human communities and especially for those regions such as south east Asia and sub-Saharan Africa[7] where such events already occur only too frequently. For floods, a increase in risk typically of a factor of 5 can be expected by 2050[8]. For the most extreme droughts that currently affect about 2% of the world's land area at any one time (20 years ago this applied to only 1% of the world's land area), recent estimates are that by 2050 over 10% of the world's land area will be so affected[9]. Further, extreme droughts will tend to be longer, measured in years rather than months, again leading to many millions of displaced people.

What about tropical cyclones (hurricanes or typhoons) – how will they be affected by global warming? The year 2005 was a record year for Atlantic hurricanes in both their number and intensity. Katrina was the costliest natural disaster in US history and Wilma was the most intense ever observed. But there is much variability from year to year in hurricane numbers and intensity (note for instance the difference between 2005 and 2006) so that neither the year itself nor the individual storms can be considered outside the range of natural variability and therefore unequivocally due to human induced global warming.

There is no evidence that the numbers of tropical cyclones will increase with increased greenhouse gases. However, the intensity of storms is connected with the ocean surface temperature in the region where the storms develop, not surprisingly so because the main energy source for such storms comes from the latent heat released as water vapour condenses. Two papers published in mid 2005[10] before Katrina struck studied the incidence of Atlantic tropical cyclones over the last 30 years and suggested that the rising trend during this period in the proportion of the most intense tropical storms is connected with a warming of about 0.5ºC of ocean surface temperature over the region. As ocean temperatures rise at an increased rate in the future, an increase in the number of the most intense cyclones can be expected although there is uncertainty over just how large this increase might be.

Sea level rise, changes in water availability and extreme events will lead to increasing pressure from environmental refugees. A careful estimate[11] has suggested that, due to climate change, there could be more than 150 million extra refugees by 2050.

In addition to the main impacts summarised above are changes about which there is less certainty, but if they occurred would be highly damaging and possibly irreversible. For instance, large changes are being observed in polar regions. With the rising temperatures over Greenland, it is estimated that melt down of the

[5] from Schar et al,2004, Nature 427, 332-6.

[6] Jonkman, S.N. 2005 Natural Hazards **34,** 151-175; the losses due to flooding only include those from rainfall and not those from storm surges from the sea for instance in tropical cyclones.

[7] Defined according to the Palmer drought index that distinguishes between moderate, severe and extreme drought.

[8] See for instance T. N. Palmer and J. Raisanen, 2002, *Nature* 415, pp512-14.

[9] E J Burke, S J Brown and N Christidis, 2006, J Hydrometeorology, 7, *pp* 1113-1125

[10] K Emmanuel, 2005 Nature, 436, pp 686-688; P J Webster et al, 2005, Science 309, pp1844-1846

[11] Myers, N., Kent, J. 1995. *Environmental Exodus: an emergent crisis in the global arena*. Washington DC: Climate Institute.

ice cap could begin during the next few decades. Complete melt down is likely to take many centuries but it would add 7 metres (23 feet) to the sea level.

A further concern is regarding the Thermo-Haline Circulation (THC) – a circulation in the deep oceans, partially sourced from water that has moved in the Gulf Stream from the tropics to the region between Greenland and Scandinavia. Because of evaporation on the way, the water is not only cold but salty, hence of higher density than the surrounding water. It therefore tends to sink and provides the source for a slow circulation at low levels that connects all the oceans together. This sinking assists in maintaining the Gulf Stream itself. In a globally warmed world, increased precipitation together with fresh water from melting ice will decrease the water's salinity making it less likely to sink. The circulation will therefore weaken and possibly even cut off, leading to large regional changes of climate. Evidence from paleoclimate history shows that such cut-off has occurred at times in the past. It is such an event that is behind the highly speculative happenings in the film, The Day after Tomorrow.

I have spoken so far about adverse impacts. You will ask, 'are none of the impacts positive?' There are some positive impacts. For instance, in Siberia and other areas at high northern latitudes, winters will be less cold and growing seasons will be longer. Also, increased concentrations of carbon dioxide have a fertilising effect on some plants and crops which, providing there are adequate supplies of water and nutrients, will lead to increased crop yields in some places, probably most notably in northern mid latitudes. However, careful studies demonstrate that adverse impacts will far outweigh positive effects, the more so as temperatures rise more than 1 or 2 ºC (2 to 3.5 ºF) above preindustrial (Fig 5).

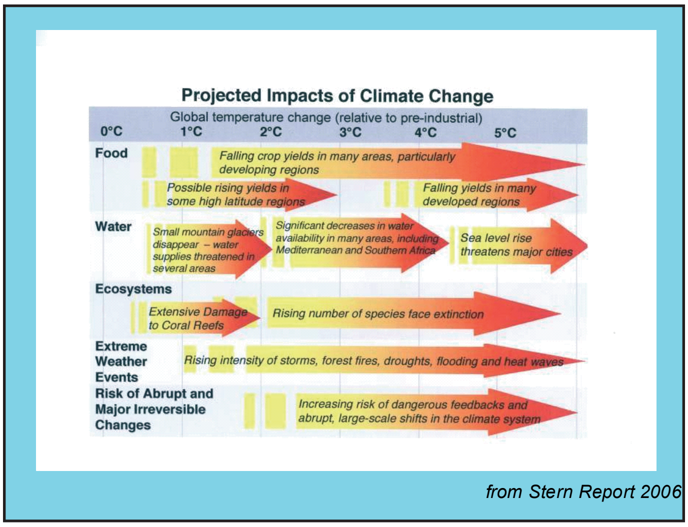


Fig 5 Summary of impacts of Climate Change in different sectors as a function of the rise in global average
temperature (from the Stern Review on the Economics of Climate Change 2006)

In addition to the direct impact on human communities are the impacts on ecosystems with an estimated 15 - 40% of species potentially facing extinction after only 2ºC of warming. Further major irreversible impacts on marine ecosystems are likely because of acidification of ocean water as a direct effect of rising carbon dioxide levels.
A recent review of the economics of climate change by Sir Nicholas Stern[12] provides estimates of the likely cost of climate change impacts supposing no mitigation action is taken. I quote from the report's summary.

"In summary, analyses that take into account the full range of both impacts and possible outcomes – that is, that employ the basic economics of risk – suggest that 'business-as-usual' climate change will reduce welfare by an amount equivalent to a reduction in consumption per head of between 5 and 20%. Taking account of the increasing scientific evidence of greater risks, of aversion to the possibilities of catastrophe, and of a broader approach to the consequences than implied by narrow output measures, the appropriate estimate is likely to be in the upper part of this range."

These estimates in economic terms do not take into account the human cost in terms of deaths, dislocation, misery, lack of security etc that would also accompany large scale climate changes. Nor do they emphasise sufficiently the predominance of impacts in poor countries.

Can we believe the evidence

Many people ask how certain is the scientific story I have just presented. Let me explain that it is based very largely on the very thorough work of the Intergovernmental Panel on Climate Change (IPCC)[13]. I had the privilege of being chairman or co-chairman of the Panel's scientific assessment from 1988 to 2002. The IPCC has produced three assessments - in 1990, 1995 and 2001 – covering science, impacts and analyses of policy options. The IPCC 2001 report is in four volumes, each of about 1000 pages and containing many thousands of references to the scientific literature[14]. A fourth report will be published in 2007; the Summary for Policymakers of the science of this report is already available on the IPCC web site. It confirms the main conclusions of previous reports, and, in the light of six more years of climate change

[12] commissioned by UK government, to be published by Cambridge University Press, December 2006

[13] The IPCC was formed in 1988 jointly by two UN bodies, the World Meteorological Organisation and the United Nations Environment Programme.

[14] *Climate Change 2001* in four volumes, published for the IPCC by Cambridge University Press, 2001. Also available on the IPCC web site www.ipcc.ch. My book, John Houghton, *Global Warming: the complete briefing*, 3rd edition, Cambridge University Press, 2004 is strongly based on the IPCC reports.

observations and research, is able to express them with greater certainty. Several thousand scientists drawn from many countries were involved as contributors and reviewers in these assessments. Our task was honestly and objectively to distinguish what is reasonably well known and understood from those areas with large uncertainty and to present balanced scientific conclusions to the world's policymakers. No assessment on any other scientific topic has been so thoroughly researched and reviewed. In June 2005, just before the G8 Summit in Scotland, the Academies of Science of the world's 11 most important countries (the G8 plus, India, China and Brazil) issued a statement endorsing the conclusions of the IPCC and urging world governments to take urgent action to address climate change. The world's top scientists could not have spoken more strongly.

Unfortunately, there are strong vested interests that have spent tens of millions of dollars on spreading misinformation about the climate change issue[15]. First they tried to deny the existence of any scientific evidence for rapid climate change due to human activities. More recently they have largely accepted the fact of anthropogenic climate change but argue that its impacts will not be great, that we can 'wait and see' and in any case we can always 'fix' the problem if it turns out to be substantial. The scientific evidence cannot support such arguments.

International Action

Because of the work of the IPCC and its first report in 1990, the Earth Summit at Rio de Janeiro in 1992 could address the climate change issue and the action that needed to be taken. The Framework Convention on Climate Change (FCCC) - agreed by over 160 countries, signed by President George Bush Snr for the USA and subsequently ratified unanimously by the US Senate – agreed that Parties to the Convention should take "precautionary measures to anticipate, prevent or minimise the causes of climate change and mitigate its adverse effects. Where there are threats of irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures."

In combating climate change, action has to be of two kinds, adaptation and mitigation. Because of the substantial commitment that to climate change that is already in train, much attention needs to be given to means of adapting to it so as to limit the damage for instance from sea level rise or extreme events. Here, I will largely concentrate on the mitigation of greenhouse gas emissions in order to slow climate change and eventually halt it.

[15] George Monbiot's book *Heat*, 2007, chapter 2, provides detail of this misinformation campaign.

More particularly the Objective of the FCCC in its Article 2 is "to stabilise greenhouse gas concentrations in the atmosphere at a level that does not cause dangerous interference with the climate system" and that is consistent with sustainable development. Such stabilisation would also eventually stop further climate change. However, because of the long time that carbon dioxide resides in the atmosphere, the lag in the response of the climate to changes in greenhouse gases (largely because of the time taken for the ocean to warm), and the time taken for appropriate human action to be agreed, the achievement of such stabilisation will take at least the best part of a century.

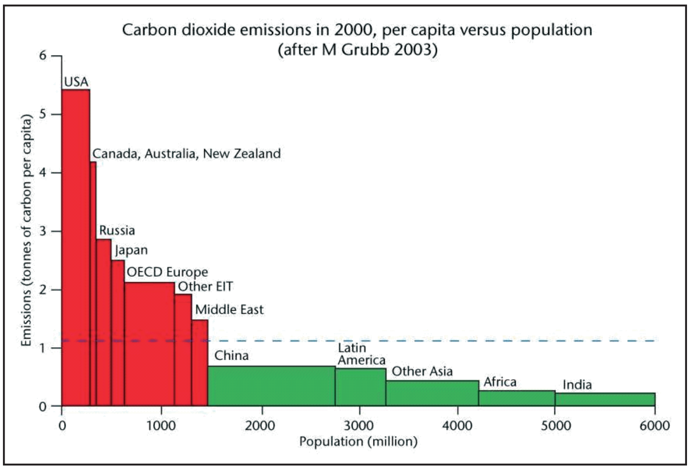


Fig 6 Carbon dioxide emissions in 2000 per capita for different countries and groups of countries[16].

Global emissions of carbon dioxide to the atmosphere from fossil fuel burning are currently approaching 7 billion tonnes of carbon per annum and rising rapidly (Fig 7a). Unless strong measures are taken they will reach two or even three times their present levels during the 21st century and stabilisation of greenhouse gas concentrations or of climate will be nowhere in sight. To stabilise carbon dioxide concentrations, emissions during the 21st century must reduce to well below their present levels by 2050 (Fig 7) and to a small fraction of their present levels before the century's end.

The reductions in emissions must be made globally; all nations must take part. However, there are very large differences between greenhouse gas emissions in different countries. Expressed in tonnes of carbon per capita per annum, they vary from about 5.5 for the USA, 2.5 for Europe, 0.7 for China and 0.2 for India (Fig 6). Further, the global average per capita, currently about 1 tonne per annum, must fall substantially during the 21st century. The challenge is to find ways to achieve reductions that are both realistic and equitable. I return to this issue later.

[16] After M.Grubb *World Economics 3*, p145

The FCCC recognised that developed countries have already benefited over many generations from abundant fossil fuel energy and that developed countries should therefore be the first to take action. First, developed countries were urged by 2000 to return to 1990 emission levels, something achieved by very few countries. Secondly, in 1997, the Kyoto Protocol was agreed[17] as a beginning for the process of reduction, averaging about 5% below 1990 levels by 2012 by those developed countries who have ratified the protocol. It is an important start demonstrating the achievement of a useful measure of international agreement on such a complex issue. It also introduces for the first time international trading of greenhouse gas emissions so that reductions can be achieved in the most cost effective ways.

Serious discussion is now beginning about international agreements for emissions reductions post Kyoto. These must include all major emitters in both developed and developing countries. On what eventual level of stabilisation, of carbon dioxide for instance, should these negotiations focus? To stop damaging climate change the level needs to be as low as possible. In the light of the FCCC Objective it must also allow for sustainable development.

In 1996 the European Commission proposed a limit for the rise in global average temperature from its preindustrial value of 2 ºC – that implies a stabilisation level for carbon dioxide of about 430 ppm (allowing for the effect of other greenhouse gases at their 1990 levels). In a speech in 2003, Lord John Browne, Chief Executive Officer of British Petroleum, one of the world's largest oil companies, proposed 'stabilization in the range 500-550 ppm' that 'with care could be achieved without disrupting economic growth.'

A recent more thorough appraisal of the necessary stabilization level has been made in the Stern Report commissioned by the UK government in 2006[18] that comes to the strong conclusion that the stabilization aim should be within the range of 450 to 550 ppm in terms of equivalent CO_2[19] which means a range 400 to 490 ppm in terms of CO_2 alone. The bottom end of this range is only 20 ppm above the current CO_2 level and will be reached within about a decade. The top end of this range is about equivalent to doubled carbon dioxide at its preindustrial level and a likely rise in global average temperature of about 2.5 ºC. Although climate change would eventually largely be halted – although not for well over a hundred years – as we have seen, the climate change impacts at such a level would be large. A steady rise in sea level will continue for many centuries, heat waves such as in Europe in 2003 would be commonplace, devastating floods and droughts would be much more common in many places and Greenland would most likely start to melt down. The aim should be therefore to stabilise nearer to the lower level proposed by Stern. But is that possible?

The International Energy Agency (IEA) in its World Energy Outlook 2006 is responding to the call from the G8 leaders at Gleneagles in 2005 and St Petersburg in 2006 to map a more sustainable energy future. Three scenarios are presented for the period to 2030 (Fig 7), a Reference Scenario (REF) that assumes no change in present governments' policies, an Alternative Scenario (ALT) that includes a package of environmental and energy security policies and measures that countries around the world are considering but are not yet agreed and a Beyond Alternative Policy Scenario (BAPS) that 'could be met through a set of technological breakthroughs stimulated by yet stronger government policies and measures.' Neither the REF nor ALT scenarios come anywhere near creating the turn around in the global emissions profile needed for CO_2 stabilization at the level required. The BAPS scenario is much closer but heads above the 450 ppm stabilization curve and would have to be followed by more drastic reductions after 2030 to meet 450 ppm stabilization.

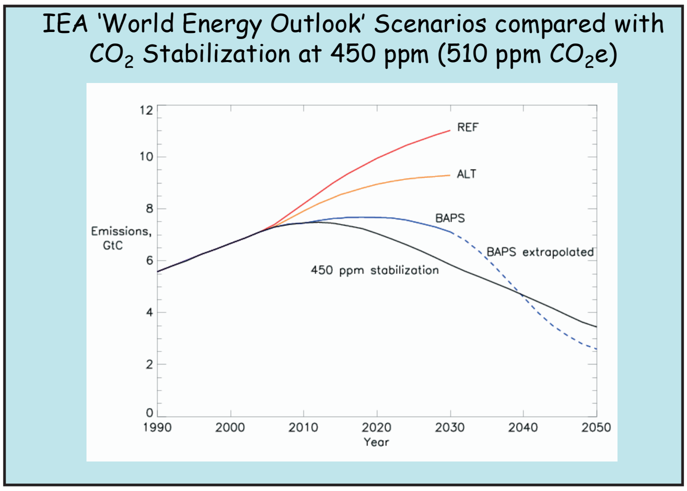


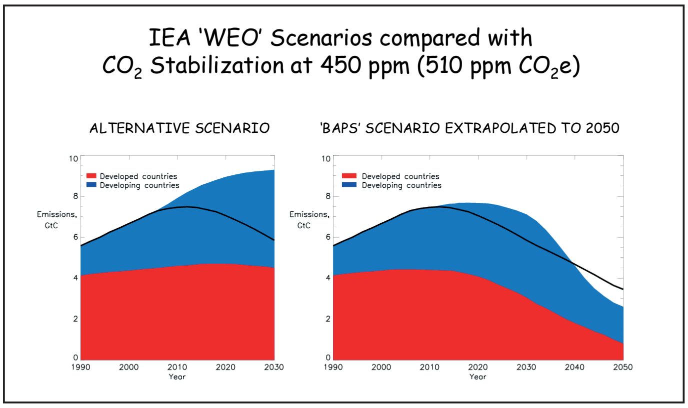
Fig 7 (a) Global emissions of carbon dioxide from fossil fuel burning (in billions of tonnes of carbon) from 1990 to 2004 actual emissions (they were 1.7 GtC in 1950) and as projected to 2050 under International Energy Agency scenarios[20] - see text for explanation. Also shown is a profile of emissions that would lead to stabilization of CO_2 concentration at 450 ppm. Also indicated is an extrapolation of the BAPS profile that would be consistent with 450 ppm CO_2 stabilization.

[17] although agreed in 1997 it did not come into force until 2005. The USA and Australia failed to ratify.

[18] commissioned by UK government, be published by Cambridge University Press, December 2006

[19] Equivalent CO_2 (often written as CO_2e) includes the effect of increases from preindustrial in the other greenhouse gases (CH_4, N_20) etc)– assumed here to be constant at their 1990 levels - expressed as an additional amount of CO_2 that would give the same radiative forcing. 450 ppm CO_2 is equivalent ot about 510 ppm CO_2e.

[20] From Energy for Tomorrow's World, World Energy Council Report, 1993



7(b) shows division into developed and developing countries; IEA division for ALT scenario and mine for BAPS (see text).

In the ALT scenario, emissions from developed countries, although growing now, fall back to their 2004 levels by 2030, while those from developing countries rise by about 85%. Under the BAPS, total global emissions fall back to their 2004 level by 2030. I have extrapolated the BAPS to 2050 (Fig 7) in a way that should eventually provide stabilization at 450 ppm; global emissions in 2050 are then about one third of their 2004 level. For the BAPS, no breakdown between developed and developing countries is provided by IEA. In drawing Fig 6b, I have assumed developed countries' emissions fall by 30% and 80% from their 2004 value by 2030 and 2050 respectively and that developing countries' emissions increase by 40% and decrease by 40% from their 2004 value by the same dates. The challenge presented to both developed and developing countries is very large.

The UK government has taken a lead on this issue and has agreed a target for the reduction of greenhouse gas emissions of 60% by 2050 that would go a long way to meet the aim of the Stern Review. Governor Schwarzenegger has proposed a target for California that is even tougher – a reduction of 80% by 2050. Whether such targets are adequate will depend on the responses of other countries and also on the emissions profiles that are followed in the period up to 2030.

The annual costs of stabilization at 450-490 ppm CO_2 (500-550 ppm CO_2e) have been estimated by the Stern Review to be around 1% of world GDP by 2050, a number that is broadly in agreement with those estimated by the IPCC in its 2001 Report. This is much less than the estimates of cost of taking no action that I mentioned earlier.

What actions can be taken?

Let me now address the actions that need to be taken if the reductions required are to be achieved. Three sorts of actions are required. First, there is energy efficiency. Very approximately one third of energy is employed in buildings (domestic and commercial), one third in transport and one third by industry. Large savings can be made in all three sectors, many with significant savings in cost. But to achieve these savings in practice will require appropriate encouragement and incentives from central and local government and a great deal of determination from all of us.

Take buildings for example. Recent projects demonstrate that 'zero energy' buildings are a practical possibility – initial costs are a little larger than for conventional buildings but the running costs a lot less. For example, in south London is the BedZED development (ZED = Zero Emissions development) – the largest carbon neutral housing project in the UK. It is a complex of 82 homes obtaining its heat and power from the use of forestry residue. But, most recent housing in Britain – built or planned – continues to be very unsatisfactory in terms of a level of energy sustainability that is easily achievable. Why, for instance, is combined heat and power (CHP) not the norm for new housing estates? Significant efficiency savings are also achievable in the transport sector, for instance with much more fuel efficient vehicles. Within the industrial sector some serious drive for energy savings are already becoming apparent. A number of the world's largest companies have already achieved savings in energy that have translated into money savings of many millions of dollars[21].

Secondly, a wide variety of non-fossil fuel sources of energy are available for development and exploitation, for instance, biomass (including waste), solar power (both photovoltaic and thermal), hydro, wind, wave, tidal, geothermal energy and nuclear. Thirdly, there are possibilities for sequestering carbon that would otherwise enter the atmosphere either through the planting of forests or by pumping underground (for instance in spent oil and gas fields). The opportunities for industry for innovation, development and investment in all these areas is large (see box).

Socolow's Wedges

A simple presentation of the type of reductions that are required has been created by Professor Socolow of Princeton University[22]. To counter the likely growth in global emissions of carbon dioxide from now until 2050, seven 'wedges' of reduction are proposed, each wedge amounting to 1 gigatonne of carbon per year in 2050 or 25 gigatonnes in the period up to 2050. Some of the possible 'wedges' he proposes are the following. They illustrate the scale of what is necessary.

- **Buildings** efficiency - reduce emissions by 25%
- **Vehicles** fuel use - from 30 to 60 mpg in 2bn vehicles
- **Carbon capture** and storage at 800 GW of coal plants
- **Wind** power from 1 million 2 MWp windmills
- **Solar** PV power from area of (150 km)^2
- **Nuclear** power - 700 GW - 2 x current capacity
- Stop tropical **deforestation** & establish 300 Mha of new tree plantations
- **Biofuel** production (ethanol) from biomass on 250Mha of land

[21] Information from Steve Howard of The Climate Group

[22] Pacala, S and R Socolow, 2004, Science 305:968-972

Many of the technologies are already available and in use or ripe for development to enable their commercial deployment. A recent study of the many possibilities, their applicability, availability and costs has been prepared by Professor Dennis Anderson of Imperial College for the Stern Review[23] . His conclusions concerning the contributions of the most promising technologies in 2050 are illustrated in Fig 8 where the largest contributions are expected from efficiency improvements, carbon capture and storage, nuclear, biofuels and solar (PV and solar/thermal).

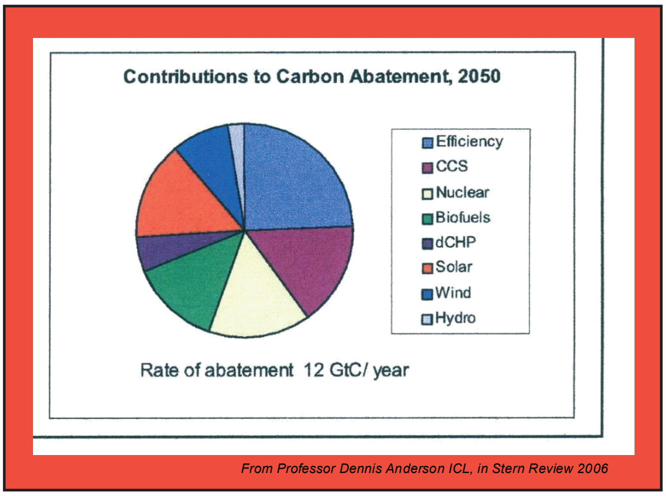


Fig 8 Possible contributions of technologies to overall global primary energy supplies in 2050
(CCS = carbon capture and storage; CHP = combined heat and power)

A long term strategy

It is of course easy to present paper solutions (see box for an example) but harder to see how they can be implemented. Questions are immediately raised such as: what are the best options? There is no one solution to the problem and no best technology. Further, different solutions will be appropriate in different countries or regions. Simplistic answers I have heard many times have been - Leave it to the market that will provide in due course, and The three solutions are Technology, Technology and Technology. The market and technology are essential and effective tools but poor masters. Solutions need to be much more carefully crafted than these tools can provide on their own. So how can the process start?

A long-term perspective is required. I like to think of it in terms of a voyage. For the boat we are taking, technology can be thought of as the engine and market forces as the propeller driven by the engine (Fig 9). But where is the boat heading? Without a rudder and someone steering, the course will be arbitrary; it could even be disastrous. Every voyage needs a destination and a strategy to reach it (see box). Let me mention five components of the strategy that should direct any solutions.

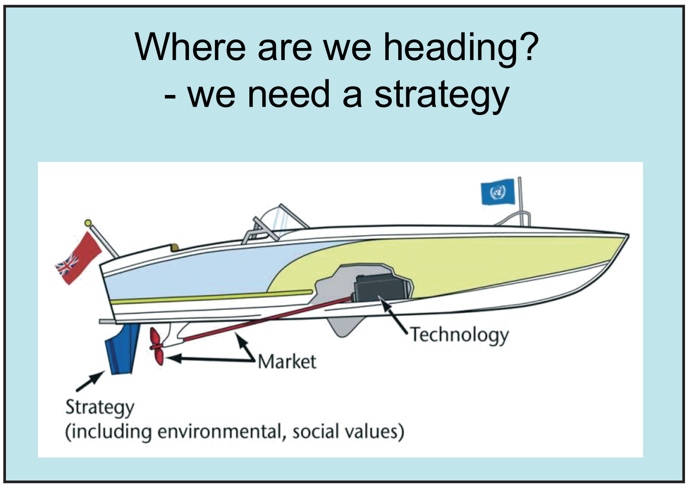


Fig 9 Where are we heading? – the need for an energy strategy. The boat flies national and UN flags to illustrate the need for national and international strategies.

Where are we heading?
Components of energy strategy

- Market and Technology tools not masters
- Long-term not only short-term
- Economy & environment considered together - internalize external costs
- Get potential technologies to starting gate – provide necessary Research and Development
- Address social & 'quality of life' values
- e.g. community benefits of local provision
- Energy security to be taken into account
- Partnerships both national and international are required to craft solutions.

First the economy and environment must be addressed together. It has been said that 'the economy is a wholly owned subsidiary of the environment'. In a speech in 2005, Gordon Brown, UK's Chancellor of the Exchequer, expanded on this idea when he said[24],

'Environmental issues - including climate change – have traditionally been placed in a category separate from the economy and from economic policy. But this is no longer tenable. Across a range of environmental issues –from soil erosion to the depletion of marine stocks, from water scarcity to air pollution – it is clear now not just that economic activity is their cause, but that these problems in themselves threaten future economic activity and growth.'

[23] available on the Stern review website under Supporting research

[24] address to the Energy and Environment Ministerial Roundtable, 15 March 2005

Take the market. It responds overwhelmingly to price and the short term. It has been effective in bringing reduced energy prices over the last two decades. But in its raw form it takes no account of environmental or other external factors. Although there has been general agreement among economists for many years that such factors should be internalised in the market, for instance through carbon taxes or cap and trade arrangements, most governments remain slow to introduce such measures. An example where it is working comes from Norway where the carbon tax that is levied makes it economic to pump carbon dioxide back into the strata from where gas is extracted. Aviation presents a contrary example where the absence of any economic measures is allowing global aviation to expand at a highly unsustainable rate.

Second, not all potential technologies are at the same stage of development. For good choices to be made, promising technologies need to be brought to the starting gate so that they can properly compete. This implies joint programmes between government and industry, the provision of adequate resources for research and development, the creation of demonstration projects and sufficient support to see technologies through to maturity[25]. The market will provide rather little of this on its own. Needed are appropriate incentive schemes. The UK Renewables Obligation scheme goes some way to providing what is required but is inadequate as it stands for bringing important technologies to the position where they can satisfactorily compete. For instance, the UK has some of the largest tides in the world. Energy from tidal streams, lagoons or barrages has the advantage over wind energy of being precisely predictable and of presenting few environmental or amenity problems. It has the potential of providing up to 20% of UK's electricity at competitive prices. Given the right encouragement and incentives, there seems no technical reason why good demonstration projects cannot be established very soon so that some of this potential can be realised within the next decade – much earlier than the timing of 'beyond 2020' that is often mentioned for this technology to be brought in. Similar potential is available from wave energy to the north and west of Britain.

A third part of the strategy is to address the social and 'quality of life' implications arising from the way energy is provided to a community. For instance, energy coming from large central installations has very different knock-on social and community effects than come from small and local energy provision. The best urban solutions may be different from what is most appropriate in rural locations. Addressing more than one problem at once is also part of this component of the strategy.

For instance, disposal of waste and generation of energy can frequently go together.
It has been estimated that the potential energy value in agricultural and forestry wastes and residues could, if realised, meet at least 10 % of the world's total requirement for energy[26] – a very significant contribution. For the UK, domestic, industrial, agricultural and forestry wastes amount to about 20 million tonnes per annum and could provide about 4% of the UK's total energy needs[27]. I have already mentioned an early example of what is being done, the south London BedZED development that obtains its heat and power from forestry residue.

Waste is just one component of biomass that is gaining increasing recognition as an important energy source. Biocrops (see box) can be employed either as fuel for power stations for electricity and hot water or for the production of liquid biofuels. There are substantial advantages in local biomass energy schemes. For instance, they can easily include Combined Heat and Power (CHP) so achieving nearly double the efficiency of schemes providing power alone. They also bring employment to rural areas and a feeling of ownership to local communities. Further, they are also more secure not being liable to political interference.

Biomass – a renewable resource

Biomass is a renewable resource. The carbon dioxide that is emitted when biomass is burnt or digested is 'fixed' in the next crop as it is grown. When fossil fuels are burnt no such replacement occurs. Because biomass is bulky, transport costs can be large. Biomass is best used therefore to provide local energy or relatively small additional feed to large power stations (for instance, it is planned that 7% of the feed to the Aberthaw power station in South Wales should be from biomass).

An ideal energy crop should have high output and low inputs; in energy terms inputs (e.g. from need for fertiliser or management) have to be less than a small fraction of energy output. These characteristics tend to rule out annual grasses such as cereals, maize and sorghum but rule in short-rotation coppice willow from a list of woody species and Miscanthus ("elephant grass") from a list of perennial grasses. An urgent need is to develop commercial technologies for biofuel production from grasses such as Miscanthus.

[25] that government energy R & D in the UK is now less than 5% of what it was 20 years ago provides an illustration of lack of commitment or urgency on the government's part.

[26] from *World Energy Outlook 2006*, IEA, Table 14.6

[27] from Biomass Task Force Report – a report to UK government, October 2005

In Upper Austria, with 1.5 million population, in 2003, 14% of their energy came from local biomass. This is planned to increase to 30% by 2010 and to continue to grow substantially thereafter. By contrast the UK raises only about 1% of its energy this way[28] – one of the lowest levels in Europe, although it would be possible to raise this to ~ 10 % by 2050[29] with use of lower grade land amounting to about 25% of the UK's total agricultural land. In the USA with a much greater area of land potentially available, the Energy Future Coalition are putting forward '25 by 25' – a target that 25% of total US energy needs should come from biomass sources by 2025. There is large potential for the development of biomass schemes, especially those using waste, in poorer countries (see box on page 17) where it is vital that local energy provision to rural areas is developed to improve their local quality of life and to enable small and medium sized industries to develop.

Solar energy schemes can also be highly versatile in size or application. Small solar home systems (Fig 10) can bring electricity in home size packages to villages in the third world – again with enormous benefits to local communities. At the other end of the size scale, but again particularly applicable to developing countries where there is plenty of sunshine, large solar thermal or PV projects are being envisaged that couple electricity and hydrogen generation with desalination in desert regions where water is a scarce resource.

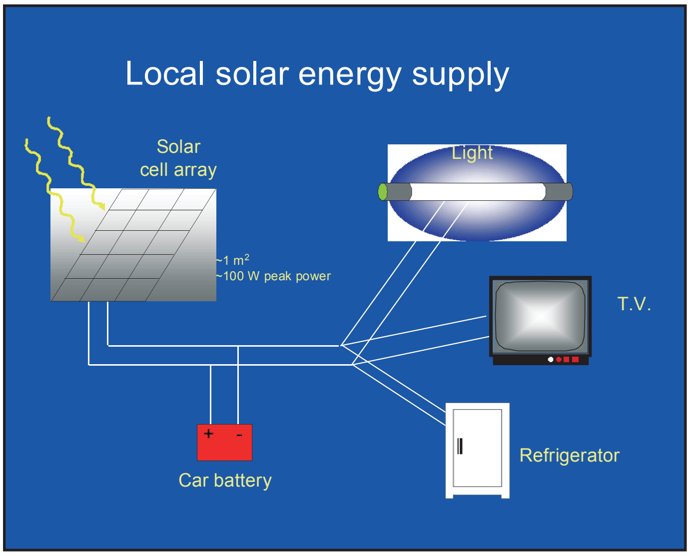


Fig 10 Solar energy schemes – a small solar home system

Fourthly, energy security must be part of the strategy and is increasingly being addressed by governments in many countries. How safe are gas pipelines crossing whole continents? How safe are nuclear power stations from terrorist attack or nuclear material from proliferation to terrorist groups? It is such considerations that put into question large expansion of the contribution from nuclear energy. However, there are hundreds of tonnes of plutonium now surplus from military programmes that could be used in nuclear power stations (and degraded in the process) assisting with greenhouse gas reductions in the medium term[30]. For countries such as China and India with rapidly increasing energy demands, abundant coal provides a cheap and secure energy source. A high priority is to work towards all new coal fired power stations being substantially carbon neutral by using the latest technology coupled with carbon capture and storage underground.

Diversity of source is clearly important. But thinking about security could be more integrated and holistic. Admiral Sir Julian Oswald, First Sea Lord over ten years ago suggested that defence policy and spending could be broadened to consider potential causes of conflict such as the large scale damage and insecurity that increasingly will arise from climate change[31]. For instance, funding on the scale of the many billions of pounds or dollars spent on the Iraq war, if directed at combating climate change would accelerate enormously the realization of greenhouse gas reductions on the scale required.

Finally, **fifthly** as is both stated and implied in the Framework Convention on Climate Change of 1992, partnerships of many kinds are required. All nations (developed and developing) need to work closely together with national, international and multinational industries and corporations to craft solutions that are both sustainable and equitable. Technology Transfer from developed to developing countries is vital if energy growth in developing countries is going to proceed in a sustainable way.

Can we wait and see?

Let me now address those who argue that we can 'wait and see' before action is necessary. That is not a responsible position. The need for action is urgent for three reasons. The first reason is scientific. Because the oceans take time to warm, there is a lag in the response of climate to increasing greenhouse gases. Because of greenhouse gas emissions to date, a commitment to substantial change already exists, much of which will not be realised for 30 to 50 years. Further emissions just add to that commitment. The second reason is economic. Energy infrastructure, for instance in power stations also lasts typically for 30 to 50 years. It is much more cost effective to begin now to phase in the

[28] from Biomass Task Force Report – a report to UK government, October 2005
[29] Royal Commission on Environmental Pollution report *Biomass as a Renewable Energy Resource* 2004
[30] Nuclear Power in the 21st century, Interdiscipinary Science Reviews, 26, 2001, Especially paper by W.L.Wilkinson, pp 303-306.
[31] Oswald J, Defence and environmental security, 1993, in Prins, G (ed) *Threats without enemies*. London, Earthscan

required infrastructure changes rather than having to make them much more rapidly later. The third reason is political. Countries like China and India are industrialising very rapidly. I heard a senior energy adviser to the Chinese government speak recently. He said that China by itself would not be taking the lead in reducing greenhouse gas emissions. When the big emitters in the developed nations take action, they will take action. China is building new electricity generating capacity of about 1 GW power station per week. An example of the effective leadership that is so urgently required can be seen in the European Union plans to build jointly with China the first carbon-neutral Chinese coal fired power station employing carbon sequestration and storage.

Stewards of creation: an ethical and Christian challenge

People often say to me that I am wasting my time talking about Global Warming. 'The world' they say 'will never agree to take the necessary action'. I reply that I am optimistic for three reasons. First, I have experienced the commitment of the world scientific community (including scientists from many different nations, backgrounds and cultures) in painstakingly and honestly working together to understand the problems and assessing what needs to be done. Secondly, I believe the necessary technology is available for achieving satisfactory solutions. My third reason is that I believe we have a God-given task of being good stewards of creation.

What does stewardship of creation mean? In the early part of Genesis, we learn that humans, made in God's image, are given the mandate to exercise stewardship/management care over the earth and its creatures (Gen 1 v26,28 & 2 v15). We therefore have a responsibility first to God to look after creation - not as we please but as God requires – and secondly to the rest of creation as ones who stand in the place of God. To expand on what this means, I quote from a document 'A Biblical vision for creation care' developed following a meeting of Christian leaders at Sandy Cove, Maryland, USA held in June 2004[32].

According to Scripture only human beings were made in the divine image (Gen. 1:26-27). This has sometimes been taken to mean that we are superior and are thus free to lord it over all other creatures. What it should be taken to mean is that we resemble God in some unique ways, such as our rational, moral, relational, and creative capacity. It also points to our unique ability to image God's loving care for the world and to relate intimately to God. And it certainly points to our unique planetary responsibility. The same pattern holds true in all positions of high status or relationships of power, whether in family life, education, the church, or the state. Unique capacity and unique power and unique access create unique responsibility. Being made in God's image is primarily a mandate to serve the rest of creation (Mk 10:42-45).

Only in recent decades have human beings developed the technological capacity to assess the ecological health of creation as a whole. Because we can understand the global environmental situation more thoroughly than ever before, we are in a sense better positioned to fulfil the stewardship mandate of Genesis 1 and 2 than ever before. Tragically, however, this capacity arrives several centuries after we developed the power to do great damage to the creation. We are making progress in healing some aspects of the degraded creation, but are dealing with decades of damage, and the prospect of long-lasting effects even under best-case scenarios.

We are only too aware of the strong temptations we experience, both personally and nationally, to use the world's resources to gratify our own selfishness and greed. Not a new problem, in fact a very old one. In the Genesis story of the garden, we are introduced to human sin with its tragic consequences (Genesis 3); humans disobeyed God and did not want him around any more. That broken relationship with God led to broken relationships elsewhere too. The disasters we find in the environment speak eloquently of the consequences of that broken relationship.

We, in the developed countries have already benefited over many generations from abundant fossil fuel energy. The demands on our stewardship take on a special poignancy as we realize that the adverse impacts of climate change will fall disproportionately on poorer nations and will tend to exacerbate the increasingly large divide between rich and poor. Our failure to be good stewards is a failure to love God and a failure to love our neighbours, especially our poorer neighbours in Africa and Asia. The moral imperative for the rich countries is inescapable.

Some Christians tend to hide behind an earth that they think has no future. But Jesus has promised to return to earth – earth redeemed and transformed[33]. In the meantime earth awaits, subject to frustration, that final redemption (Rom 8 v 20-22). Our task is to obey the clear injunction of Jesus to be responsible and just stewards until his return (Luke 12 v 41-48). Exercising this role provides an important part of our fulfilment as humans. In our modern world we concentrate so much on economic goals – getting rich and powerful. Stewardship or long-term care for our planet and its resources brings to the fore moral and spiritual goals. Reaching out for such goals could lead to nations and

[32] from an unpublished statement 'Biblical Vision for Creation Care' prepared by participants at a conference of Christian leaders at Sandy Cove Maryland, USA in June 2004.

[33] see Bishop N.T.Wright, *'New Heavens, New Earth'*, Grove Booklets B11, Ridley Hall, Cambridge, 1999

peoples working together more effectively and closely than is possible with many of the other goals on offer.

Aiming at goals

To make progress towards sustainability we need goals or targets to aim at. Any commercial company understands the importance of targets for successful business. Targets are needed at all levels of society - international, national, local and personal. Often, there is a reluctance to agree or set targets. A common question is, 'Can we not achieve what is necessary by voluntary action?' Although voluntary action has achieved a few successes, in general, it fails badly to bring about change on anything like the scale that is required.

There are many examples of international targets that have been agreed. Within the UN Framework Convention on Climate Change (FCCC), targets for reductions of greenhouse gas concentrations in some developed countries by 2012 have been set within the Kyoto Protocol. Discussions are beginning about internationally agreed targets for later dates that need to involve all major countries. In the meantime, some countries or states (e.g. the UK and California[34]) have set real or aspirational targets of their own.

At the World Summit on Sustainable Development at Johannesburg in 2002, some new targets were established for example, to halve the proportion of people without access to clean water and basic sanitation by 2015; to use and produce chemicals by 2020 in ways that do not lead to significant adverse effects on human health and the environment; to maintain or restore depleted fish stocks to levels that can produce the maximum sustainable yield on an urgent basis and where possible by 2015; to achieve by 2010 a significant reduction in the current rate of loss of biological diversity. Many felt these targets were too vague or too weak. Even so, progress with their realization is proving to be extremely slow. But at least they have provided something rather than nothing to aim at.

New Attitudes

Not only do we need goals but also new attitudes and approaches in the drive towards sustainability – again at all levels of society, international, national and individual. I mention two particular examples. First, we need to look seriously at measures of sustainability and accounting tools to apply those measures. For instance, economic performance of countries is currently measured in GDP, a measure that takes no account of environmental or indeed many other concerns; it is a measure that increases with more conflict or more crime! Although considerable effort has been put into other more appropriate measures for instance the Human Development Index (HDI), the idea of Natural Capital or the Environmental Footprint, they are inevitably more complex and none are widely used by policy makers. In many respects considerations of the economy have to take second place to those of the environment[35]. The dominance of the 'market' is often also allowed to ride over environmental considerations. The economy, the market and the principles of free trade are 'tools' – important tools, but they must not be allowed to be in the position of 'masters'.

A second example of a new attitude to be taken on board, again at all levels from the international to the individual, is that of 'sharing'. At the individual level, a lot of sharing often occurs; at the international level it occurs much less. Perhaps the most condemning of world statistics is that the rich are getting richer while the poor get poorer – the flow of wealth in the world is from the poor to the rich. Considering Aid and Trade added together, the overwhelming balance of benefit is to rich nations rather than poor ones. Nations need to learn to share on a very much larger scale.

We often talk of the 'global commons' meaning for example air, oceans or Antarctica – by definition these are 'commons' to be shared. But more 'commons' need to be identified. For instance, there are respects in which Land should be treated as a resource to be shared or fish and other marine resources. Or, in order for international action regarding climate change to be pursued, how are allowable emissions from fossil fuel burning or from deforestation to be allocated. How do we as a world share these natural resources between us and especially between the very rich – like ourselves - and the very poor?

One of the biggest 'sharing' challenges faced by the international community is how emissions of carbon dioxide can be shared fairly between nations. Fig 6 illustrates the great disparity between emissions by rich nations compared with poorer ones. The FCCC has very soon to start negotiations including all countries regarding emissions allocations. One proposal is that the starting point is current emissions, so that it is reduction levels from the present that are negotiated. That is called 'grandfathering' and tends to perpetuate current inequities. A proposal by the Global Commons Institute[36] is that emissions should first be allocated to

[34] I have mentioned earlier targets for 2050 set by the UK (60% reduction) and proposed by California (80% reduction)

[35] See for instance Jonathon Porritt, 'Capitalism as if the World Matters', Earthscan 2005

[36] called *Contraction and Convergence* - for more details see <www.gci.org.uk>

everybody in the world equally per capita, then transfer of allocations being allowed through trading between nations. The logic and the basic equity of this proposal is in principle quite compelling – but is it achievable?

Sustainability will never be achieved without a great deal more sharing. Sharing is an important Christian principle that needs to be worked out in practice. John the Baptist preached about sharing (Luke 3 v11), Jesus talked about sharing (Luke 12 v33), the early church were prepared to share everything (Acts 4 v32) and Paul advocated it (2 Cor 8 v13-15). The opposite of sharing - greed and covetousness - is condemned throughout scripture. The sharing of knowledge and skills with those in the third world is also an important responsibility (see box).

Sharing Skills with the Developing World

An aspect of 'sharing', the importance of which is increasingly recognized by agencies concerned with aid and by others, is not just to share our food or other goods with the third but to share our skills, for instance in science and technology.

I give an example from my experience as a Trustee of the Shell Foundation[37], a large charity set up by the Shell company particularly to support the provision of sustainable energy in poor countries. In general, this is not being done through grants for individual projects. It is often said that it is better to provide a hungry man with a fishing rod than with a fish. It is even better to find someone who will set up a fishing rod factory! So the Foundation's programmes are increasingly concerned with the creation of local enterprises and the loan financing to enable them to get started. Examples of such enterprises are some that build and market simple efficient stoves using traditional fuels that will substantially reduce the amount of fuel that is used and also reduce indoor air pollution with the serious damage to health that it causes, and others that provide sustainable and affordable energy to poor communities often from the use of readily available waste material (e.g. rice straw in China, coconut shells in the Philippines etc). The potential for the multiplication of such projects is large. An aim of the Foundation is to catalyse other bodies and agencies in the creation of mechanisms for the large scale-up of such programmes so that they can become significant on a global scale both in the provision of energy to poor communities and also in reducing greenhouse gas emissions.

These new attitudes are not just to provide guidance to policy makers in government or elsewhere. They need to be espoused by the public at large. Otherwise government will not possess the confidence to act. For the public to take them on board, the public have to understand them. To understand, they have to be informed. There is a great need for accurate and understandable information to be propagated about all aspects of sustainability. Christian churches could play a significant role in this.

You may ask, 'but what can I as an individual do?' There are some actions that all of us can take[38]. For instance, we can ensure our homes and the appliances or the car we purchase are as energy efficient as possible. We can buy 'green' electricity, shop responsibly, use public transportation, car-share more frequently, recycle our waste and create as little waste as possible. We can become better informed about the issues and support leaders in government or industry who are advocating or organising the necessary solutions. To quote from Edmund Burke, a British parliamentarian of 200 years ago, 'No one made a greater mistake than he who did nothing because he could do so little.'

Partnership with God

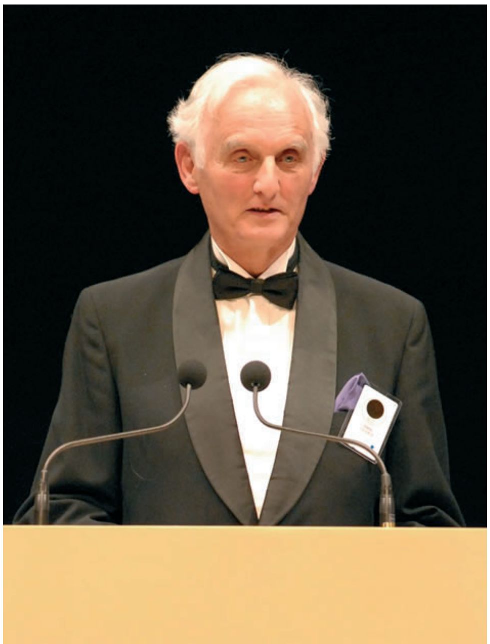
We may feel daunted as we face the seemingly impossible challenge posed by care for the Earth and its peoples and the need for sustainability. But an essential Christian message is that we do not have to carry the responsibility alone. Our partner is no other than God Himself. The Genesis stories of the garden contain a beautiful description of this partnership when they speak of God 'walking in the garden in the cool of the day' – God, no doubt, asking Adam and Eve how they were getting on with learning about and caring for the garden.

Just before he died Jesus said to his disciples, 'Without Me you can do nothing' (John 15, 5). He went on to explain that he was not calling them servants but friends (John 15, 15). Servants are given instructions without explanation; as friends we are brought into the confidence of our Lord. We are not given precise prescriptions for action but are called to use the gifts we have been given in a genuine partnership. Within the creation itself there is enormous potential to assist us in the task; the pursuit of scientific knowledge and the application of technology are an essential part of our stewardship. Both need to be approached and used with appropriate humility.

An unmistakable challenge is presented to the world wide Christian church to take on the God-given responsibility for caring for creation. It provides an unprecedented mission opportunity for Christians to take a lead and demonstrate love for God the world's creator and redeemer and love for our neighbours wherever they may be – remembering the words of Jesus, 'From everyone who has been given much, much will be demanded' (Luke 12 48).

[37] <www.shellfoundation.org>

[38] see, for instance, 'For Tomorrow Too', booklet from Tearfund, www.tearfund.org 2006



Sir John Houghton CBE FRS was co-chairman of the Scientific Assessment for the IPCC from 1988-2002. He was previously chairman of the Royal Commission on Environmental Pollution (1992-1998), Chief Executive of the Meteorological Office (1983-1991) and Professor of Atmospheric Physics, University of Oxford (1976-1983). He is currently Honorary Scientist at the Hadley Centre, a Trustee of the Shell Foundation, and President of The John Ray Initiative.

Sir John Houghton receiving the Japan Prize in 2006

JRI Briefing Paper No 14

Global Warming, Climate Change And Sustainability: Challenge to Scientists, Policy Makers and Christians

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