# Global Warming

Price 50p

## In the beginning

Until about 2 billion years ago the Earth's atmosphere was rich in carbon dioxide ($CO_2$). Then, as the Earth cooled, the $CO_2$ began to combine with nutrients in the oceans to produce organic material. Oxygen was released. Dead material sank to the ocean floor and, over the passage of millions of years, was trapped, heated, pressed and converted to the oil and gas we use today. Land based vegetation later was converted to coal. When we burn these 'fossil' fuels we are reversing millions of years of geological process.

## Is global warming happening and how?

It is not disputed that the Earth's atmosphere insulates us from space and, like double glazing, keeps us warmer (by about 33°C) than would otherwise be the case. Around the end of the 19th century a Swedish scientist, Arrhenius, who was seeking to explain the rise and fall of global temperatures and the consequent Ice Ages, postulated a link with $CO_2$ levels. Given the harshness of Northern European winters he decided a little warming was desirable! Subsequently scientists drilled through hundreds of thousands of years of ice in Antarctica and measured the $CO_2$ trapped in the air bubbles at different ages. These showed a clear relationship between $CO_2$ levels in the atmosphere and temperature and also that the Earth has been both warmer and cooler than now in the past. However, though $CO_2$ levels have varied in the past, they are now above anything found in the last 650,000 years. In 2005 the concentration was 379 parts per million (ppm) compared to 180-300 ppm previously and about 280 ppm immediately before the industrial revolution.

Until the 1950s however it was believed that any man made $CO_2$ emissions would be absorbed by the natural ocean and forest sinks. This was true at that time but in 1957 two American scientists, Revelle and Seuss, showed that the capacity of the natural systems to absorb $CO_2$ was much lower than had been thought and, critically, that if fossil fuel use *continued to increase,* $CO_2$ concentrations would ultimately effect global temperatures. In 1957 they were not sure any rise had occurred but this was a wake up call. Two decades of monitoring and study followed during which suspicions grew. In 1979 scientists gathered for the Geneva World Climate Conference and in 1988 political leaders became involved for the first time through a World Meteriological Organization and UN Environmental Programme conference at Montreal. It was agreed that the *possibility* of man influenced climate change was of sufficient concern that a supra national scientific body should study it. That body is the Intergovernmental Panel on Climate Change (IPCC).

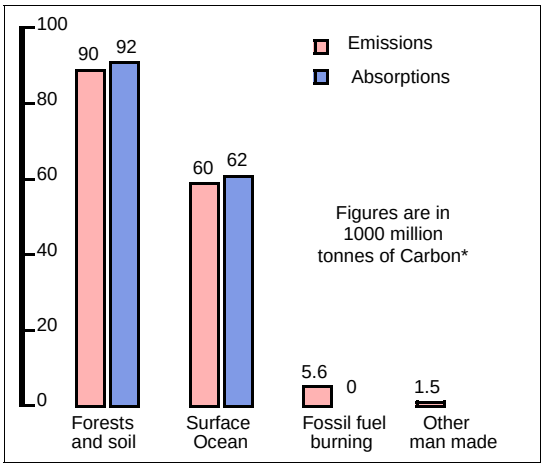


*Fig 2. The Carbon balance 1990 (IPCC)*

A great deal of data has been and continues to be collected. Fig 1 for example shows the average annual temperatures in the Northern Hemisphere over the last millennium. It uses actual recorded temperatures for the last 150 years and then 'proxies' such as the width of tree rings (which are wider in warm years than cold) to estimate temperatures. Average temperatures have never been higher in that thousand years than today. Indeed the initial trend was down. More significantly the *rate* of increase has never been so fast.

We know in this country that the weather varies enormously. Severe winters follow mild ones, wet and windy summers follow hot ones. It is very difficult to be sure that a few hot summers in succession are part of a long term trend or simply part of the natural variation in our climate. It is known that temperature is linked to an 11 year sun spot cycle; that the distance between sun and Earth varies a little; and that the sun's actual activity varies too. It is also realised that the natural movement of $CO_2$ to and from the oceans and forests (see Fig. 2) dwarfs the contribution (by over 20 times) made by burning fossil fuels and deforestation, and that the figures of 'natural' movement are necessarily only 'best estimates'.

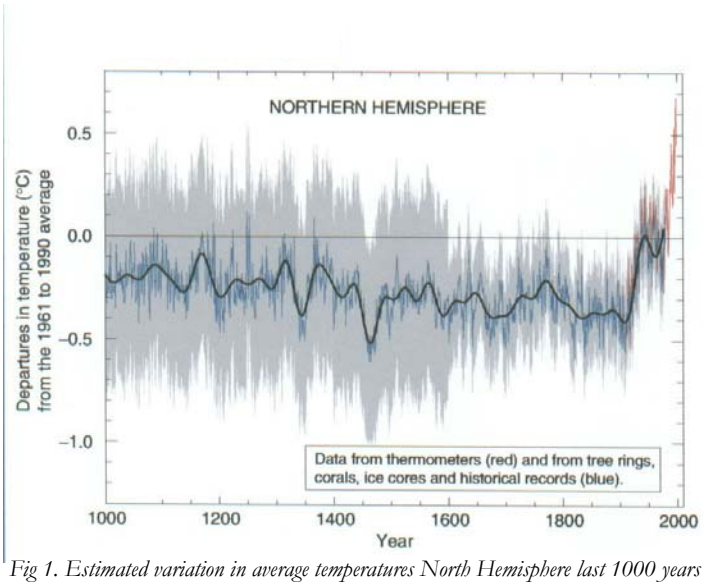


*Fig 1. Estimated variation in average temperatures North Hemisphere last 1000 years*

** Carbon dioxide emissions are often quoted 'as carbon'. 1 tonne of $CO_2$ is 0.2727 tonnes 'as carbon'. 1000 million tonnes of $CO_2$ 'as carbon' is the same as 3,670 million tonnes of $CO_2$.*

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This note has been written for ALDES by Richard Balmer and David Nowell. It should be factually accurate but any opinions expressed are the authors alone. If you see errors or have comments please email Richard Balmer at richard_balmer@blueyonder.co.uk

Nonetheless when the IPCC reported in 2007 they concluded that (a) very little increase in global temperature occurred in the 19th century (b) the average increase in the last hundred years (1906-2005) was 0.74° C with (c) 0.65° C occurring in the last 50 years (both figures within ranges) They also showed changes were uneven. There were higher increases over land than ocean and twice the average in the Arctic regions, but temperatures actually *decreased* over Antarctica.

The IPCC set up 3 working groups of which the most important is probably IPCC-1 based at the Hadley Centre for Climate Prediction in the UK. IPCC-1 was asked to produce a 'model' (a mathematical formula) of the factors which could explain why global temperatures had changed since 1860. If the model *required* substantial inclusion of man made factors this would be highly significant and would demand a *political* response. The model could then be used to forecast how far and how fast temperatures might rise in the future under different scenarios.

The IPCC groups reported for the fourth time in 2007. IPCC-1 concluded that it is now 'highly likely' (that is 90% certain) that man is responsible for at least some of the warming since 1860. In the 1990s man was adding about 6,400,000,000 tonnes, that is 6.4 gigatonnes (Gt) of carbon from fossil fuel burning each year. In the period 2000-2005 this had risen to 7.2 Gt with a further 1.6 Gt being added through land use changes such as deforestation. About half was being absorbed by forests, soils and ocean leaving 4.4 Gt to add to the 840 Gt of carbon (2005 figure) already there. The amount was therefore increasing by about $^1/_2$ %/year, and the $CO_2$ concentration by about 2 ppm/year.

Calculating the actual warming effect from this increase is complex. $CO_2$ is only one greenhouse gas. Water vapour is actually the most important, responsible for 21°C of the 33°C 'basic' warming. Heating the atmosphere will increase the water vapour it holds but also the area of cloud which reflect sunlight *away from* the Earth. Ozone adds 2°C of the warming and $CO_2$ 7°C of the remaining 10°C**

Cutting a detailed story short the IPCC now believe that the increasing greenhouse gas concentrations were warming the Earth at a rate of 3 Watts/square metre (W/m²) in 2005 but that between 40 and 50% of this was being offset primarily by the presence of aerosols (basically particles of dust from fossil and biomass burning) which have increased the amount of cloud cover and reflected more sunlight away. The *net* 1.6 W/m² warming is small compared to the gross 342 W/m² received continuously from the sun.

IPCC-1 used the model to forecast outcomes. To do this they constructed a group of different but nonetheless plausible scenarios of human development. Again cutting a detailed story short they concluded temperatures would increase by between 1.8 °C (B1, the best case) and 4.0 °C (A1F1, the worst case) (both figures again between statistical ranges) and that sea levels would rise by between 18-38 cm (best case) and 26-59 cm (worst case) above 'end 20th century' (1980-1999) levels by the end of the 21st century..

## What will the consequences be?

Apart from the obvious warming the main focus has been on the rise in sea levels. This will be due to expansion of the water in the oceans rather than melting glaciers and ice caps. It is true there are huge quantities of water stored as ice in the Antarctic and Greenland ice caps. The ice sheet in Greenland is 3000 metres thick in places. If all melted, sea levels would rise by around 7 metres, though this would not happen quickly. The Hadley Centre calculate that if emissions stabilise at around 1100 ppm (twice the original target figure) half the sheet would melt in 1000 years and the whole within 3000. The West Antarctic sheet is smaller but sea levels would still rise by some 5 metres if this melted. If the much larger East Antarctica sheet melted sea levels could rise by a further 70 metres. Ice sheet melting is not causing concern.

Sea levels rose by only 3.1 mm/year between 1993 and 2003 so problems in, say, the next 20 years are likely to be minor. In the longer term the obvious losers will be poor low lying countries such as Bangladesh or islands like the Maldives. Ultimately, though a rise of 1 metre would threaten only 3% of global land area, this equates to 33% of cultivated land. In Bangladesh 10% of the people (10 million) would need new homes unless flood defences were constructed as in Holland.

A modest rise in global temperatures would not be universally bad. Crop yields in Canada and Russia for example should rise. There would be less need for central heating in many countries and a net reduction in deaths caused by extreme hot and cold weather in northern countries.

Unhappily other land will become hotter, drier and less productive. Demands for air conditioning will increase, which is a concern because it takes twice as much energy per °C to reduce temperatures as to increase them. Storms in the UK are likely to become more intense (more tropical) because there will be more energy in the weather systems. There may be more rain in the winter and less in summer which is a concern for water supplies which are under stress in the South East; for storm water drainage systems which will struggle to cope with more violent storms; and for both ordinary houses and bigger structures like high buildings and bridges. Until recently these were designed for historic wind and rain intensities but if, as is likely, they are still around in 50 or 100 years' time the design conditions will be exceeded and they will be more vulnerable. New structures have margins built in but it is not certain whether these are too little or, indeed, too much. Insurers are worried.

A further concern is the effect on natural eco systems. Since 1978 the area of Arctic ice has decreased by 2.7%/decade and summer ice by 7.4%/decade. Indeed in 2007 it was possible to navigate the North West Passage for the first time. The loss of ice is reducing the area of habitat supporting seals and, because seals represent the main food for polar bears, bear numbers will inevitably decline. Elsewhere some plants will decline affecting habitat for insects and steps in the food chains. Nature can adjust to slow changes but not rapid ones.

The most serious possibilities however are political and rarely mentioned. First, if land becomes untenable, for example in sub Saharan Africa, there will be large scale destabilising migrations of people to countries nearby and then to more favoured areas such as Europe. Second, unless the nations of the world can agree an equitable basis for coping with global warming, there will be potential for conflict between those making sacrifices and those not, as well as conflict over limited resources such as water. The gist of the UK commissioned Stern Report was that outcomes were generally unfavourable and the sooner action was taken the

*** The 5 other 'man influencing' gases are methane, nitrous oxide, sulphur hexafluoride, and the families of hydrofluorocarbons and per fluoro-carbons.*

*Ozone is also a greenhouse gas but is largely produced by natural mechanisms rather than man and action is being taken to maintain it because it screens out harmful ultra violet light.*

better and the less costly.

## Are there other worries?

It could be suggested that it won't matter if we miss the targets by 'a bit' but there are 2 so called 'feedback loops' which cause particular concern. The first is that as the Earth warms the amount of snow and ice cover will reduce in area which will *reduce* the amount of sun light reflected back to Space, *increase* the net warming and *reduce* the snow cover further so that the warming gets faster and faster. The second 'loop' is that warming will release methane from the permafrost regions which, in the Northern Hemisphere, have already decreased by 7% since 1900. Methane is the second most important man-influencing greenhouse gas so faster warming could accelerate its release***.

A more local concern is the future of the Gulf Stream which contributes to the higher than usual temperatures at the UK's latitude. Cold water is heavier than warm water and the more salt it contains the heavier it is. In the North Atlantic there are 2 areas cooled by cold winds. One is off Labrador and the other between Greenland, Iceland and Norway. As the surface water cools it freezes, releasing salt, and this cold, saltier water sinks and runs southwards towards the Equator with a flow estimated as 100 times that of the Amazon. It is replaced by warm surface water from the Gulf of Mexico, the current we know as the Gulf Stream. If this 'stirring' of the North Atlantic ceased, the UK would not receive the warming it now receives and would, paradoxically, become about 5 $^{o}$C cooler than now over a period of 10 or 20 years despite global warming. Currently the Hadley Centre's research suggests that while the strength of the Gulf Stream might diminish by 20% by 2050 and a little more later, it is unlikely to cease altogether.

## So what should be done?

Some say do nothing. Technology and the market will come up with a solution in plenty of time. Oil and gas prices will rise as reserves diminish (though in truth not fast enough to run out in time) and force the market to find alternative solutions. Furthermore it is unfair to ask poor countries to take expensive precautionary action when, if they exploit cheap fossil fuels now, they will be better able to afford remedial action later.

It must be remembered that global warming is a relatively new problem. It is being caused by a multiplication of a growing global population and increasingly affluent lifestyles. Had global population levelled off at its 1960 level of 3 billion the world could adjust with little pain. One clear solution is simply to reduce population. A policy which persuaded couples to 'stop at 2' would halve UK population in little more than a century and global population some time later. Such a policy would reduce pressure on wild life habitat including fish in the oceans, on land and all other resources.

**** While $CO_2$ is responsible for about 62% of the warming and receives most attention the effect of methane should not be ignored. Agricultural scientists are seeking to reduce the flatulence (and hence methane) from livestock. There are an estimated 1.4 billion cows in the world, each producing about 500 litres of gas a day or 14% of all methane emissions. Changing their diet could reduce this by as much as 70%. The destruction of bogs is a further concern. Bogs are thought to hold 21% of all land based carbon and store 4 times the amount per hectare stored in forests. Burning peat for fuel puts $CO_2$ into the atmosphere and draining bogs to create agricultural land releases methane. Methane is also released from rice paddies as well as the melting permafrost in northern latitudes noted above.*

The growing awareness by the international community (or some of it) that a problem existed led to the signing of the United Nations Framework Convention on Climate Change (UNFCCC) at the 'Earth' summit at Rio de Janeiro in 1992. Basically this committed all signatories to 'do something' about global warming and specifically encouraged the developed nations to get their emissions of greenhouses gases back to 1990 levels by the year 2000. The UK achieved this fortuitously by replacing coal fired with gas power stations and exporting a further chunk of its manufacturing industry, but others failed. Then, at the 3rd meeting of the parties to the Convention in 1997 at Kyoto, a protocol was agreed intended to commit industrialised countries (the so called Annex 1 group which include all the developed countries and others in transition to a market economy (mostly in the former USSR)) to reduce the emissions of the 6 greenhouse gases to 5.2% below the 1990 levels by 2008-2012. The EU undertook to make reductions of 8% and, within the EU, the UK pledged to reduce by 12%. The Kyoto Protocol became binding on 16th February 2005 when Russia became the 153rd country to ratify it bringing, more importantly, the proportion of Annex 1 country emissions above the threshold 55%. Unhappily the USA, a key Annex 1 country, has not signed and Australia (whose per capita use exceeds America's) only signed at end 2007. Worse, the Middle Eastern oil states, whose use of fossil fuels is excessive, and China who, due to its huge population, is the largest $CO_2$ emitter in the world, are not included in the Annex 1 group.

If the $CO_2$ concentration in the atmosphere could be limited to a specific figure a new equilibrium global temperature would eventually be reached, higher than now but not necessarily disastrously so. This was the notion proposed by the IPCC in its 3rd report. They called for a 60% cut in greenhouse gas emissions by 2050 to reduce them to the level the natural systems could absorb. They estimated this would mean $CO_2$ concentrations in the atmosphere plateau-ing off at 550 ppm (twice the pre industrial revolution concentration of 280 ppm) with temperatures only 2 $^{o}$C more than in 1990.

The 4th report was more pessimistic. To limit the rise to 2 $^{o}$C above 1990 levels (c. 2.8 $^{o}$C above pre-industrial levels) the IPCC believed $CO_2$ concentration should not exceed 440 ppm with total greenhouse gas concentration at 535 ppm $CO_2$ equivalent. To limit the rise to the safer 2$^{o}$C above *pre-industrial* levels the $CO_2$ concentration should not exceed 400 ppm. The recession will help but as concentrations have been going up by about 2 ppm/year this remains a very tough call.

## What has happened so far?

The 'Kyoto' mechanisms give credit to countries helping each other bring greenhouse gas emissions down by allowing emissions trading. The logic is that savings might as well be made where it is cheapest to do so. The 41 Annex 1 countries have provided data to the UNFCCC on greenhouse gas emissions since 1990. Performance in the period 1990-2002 varied enormously. Spain and Portugal both increased their emissions by 40.5% whereas Russia reduced its by 38.5% and Lithuania by 65.7%. The UK reduced by 15%, with $CO_2$ cut by 8%, methane by 43% and nitrous oxide by 40%. In contrast the USA total emissions were 13% *higher* with $CO_2$ 16% up, methane 7% down and nitrous oxide 6% up.

In total the Annex 1 countries emitted about 6% less greenhouse gas in 2002 than 1990 which means the Kyoto target should be achieved but the savings have levelled off and the reduction, only 5.2% over 20 years, is far less than is

needed. Moreover, as stated earlier, the Annex 1 countries do not include China, India and other major economies where greenhouse gas emissions continue to rise. Global greenhouse gas emissions were 24% higher in 2004 than 1990.

In December 2009 national leaders gathered in Copenhagen to agree action post Kyoto. The conference was a success only in that nearly every country attended. The EU was the sole group to emerge with credit with, it must be said, the UK leading within it. American and Chinese offers fell way short of anything useful and poorer countries demanded costs of mitigation fall exclusively on richer countries, ignoring the employment consequences of this expectation.

## Why cannot the World agree to take action?

Bluntly the answer is that it is unpopular. It is difficult to find a country whose whole political philosophy is not dominated by the imperative of 'increasing standards of living' which means enjoying more of everything - goods like cars and services like travel - all of which need energy. The world is in a closing vice of rising population numbers on one hand and rising expectations on the other. The Chinese have put the point well. "If we can not meet the expectations of our 600 million poor, they will end up overthrowing us". The modern miracle of television can now excite the aspirations of even the very poor viewing a communal TV in their village.

Much is being done in rich countries to persuade citizens to voluntarily use less energy and consequently less fossil fuel. More could be done by legislating for more efficient energy use, for example in insulation standards in buildings, and reinforcing this by raising the price of energy through a carbon tax to provide stronger market incentives.

Unfortunately both countries and campaigners are still trying to be 'picky' about the options they will accept when, frankly, *everything* needs to be used. Wind power has reached commercial viability but is still being opposed. The largest non-fossil alternatives to produce electricity are nuclear power and large hydro electric dams but these too are opposed. GM technology is opposed even where it can increase agricultural productivity and create space for growing energy crops including bio-fuels. Countries are reluctant to see populations decline due to the perceived problems of paying pensions and caring for the elderly, even though the alternative of steadily growing numbers is no more sustainable than the pyramid theory of selling.

Among the potential technologies to reduce $CO_2$ (or buy time at least) is to plant trees, but even this is not straight-forward. Take up of carbon in the tropics is fast but slows as one goes north and eventually the loss of smooth snow cover (which reflects sunlight) means extra trees do more harm than good. In any case there is too little land available in the UK, the EU or even the world to store all the carbon needed. A more complicated technique is to capture $CO_2$ where it is produced in large volumes, such as power stations, and pipe it away to be buried underground, for example in exhausted oil and gas fields. Trials of 'CCS', carbon capture and sequestering from coal fired stations, are beginning. A wilder idea is to 'fertilize' the oceans to accelerate marine vegetation growth so that it absorbs more $CO_2$. Some years ago there was a serious proposal to spread sewage sludge in an area of sea. A more recent idea is to seed the ocean with iron which is thought to be the limiting nutrient for the growth of algae. A further Japanese idea is to grow sea weed in the ocean for fuel just like growing fuel crops on land. Another recent idea is to seed the high atmosphere with crystals to increase reflective cloud cover. The problem with all these so called geo-engineering ideas is to trial them on a large enough scale without risking the planet if they go wrong.

## What will happen?

The lessons of history are not encouraging. Awareness in the richer countries is growing but merely increasing recycling and fitting efficient light bulbs is not enough. Most rich countries are democracies with 3 to 5 year electoral cycles where matters such as health, education and transport remain more important. It is easy to introduce legislation after a disaster which has demonstrated a need but global warming is like a slow burning fuse not yet a clear, obvious disaster.

A fundamental problem is that higher energy costs put one country's manufacturing at a disadvantage. Jobs are threatened but nothing gained by moving them to China. Competing countries need to agree to raise energy prices and these agreements have to be watertight, but the world is not good at reaching agreements let alone watertight ones.

In truth politicians are desperately hoping that technology will bail them out saving them from election losing 'hair shirt' changes. Meanwhile engineers and scientists, buoyed by their incredible achievements in the past 250 years, remain not just willing to do their best but optimistic that they can make key breakthroughs such as finding the holy grail of carbon free energy. Is this optimism justified? Maybe.

There is certainly potential to deliver more energy via electricity and a low carbon mix of nuclear, large hydro, wind, biomass and tidal renewables (plus solar in sunnier countries), and fossil with CCS, could provide heat and power electric vehicles as well as supply the electricity now used.

Unhappily there will still be haggling over shares. Will poorer countries continue to demand that richer ones have a smaller per capita allowance because they have been responsible for most excess $CO_2$ already there? If shares are based on per capita allowances, are the population figures to be at the start of any agreement or at the end when, in many countries like India, populations will be much larger? Should some form of family planning policy be mandatory? Should the energy content of *imported* goods count against a country's allowance and how is this to be recorded and calculated? What special cases deserve extra allowances? Should hot countries (and cold ones) be allowed more, or those with few renewable sources? Nor has anyone begun to consider the verification needed to stop dishonest reporting, or the sanctions needed to punish offenders. All this will take time: something the world does not have.

There are some glimmers of light. There is an 'Adaptions' fund and proposals for technology transfer and the reductions of emissions from deforestation. The EU has given leadership. The EU has realised that unlike previous peoples who, unable to survive on their own land, could move elsewhere, we are tampering with the whole planet. We have to change. We have nowhere else to go.