Starting point for Pan Bulletin (from Nutshell)

The enhanced greenhouse effect

The evolution of the Earth's atmosphere

When our planet was very young it did not have an atmosphere. But, as time went by, gases emitted from the Earth's crust and from volcanoes accumulated at the surface. These gases were probably similar to those emitted from volcanoes today, which leads us to suspect that when the earliest forms of life came into existence the atmosphere consisted mainly of nitrogen and carbon dioxide, but without any oxygen.

The first living things were single-celled bacterium-like organisms which, except for sub-cellular viruses, were the only form of life on the planet for a thousand million years, and their immediate sources of energy were complex energy-containing chemical compounds that had been formed through the action of UV radiation and of electrical discharges in storms.

It was the emergence in evolution of *photosynthesis* that resulted in the eventual accumulation of oxygen in the atmosphere, and which made possible the evolution of more complex forms of life, including the plants and animals of the present day. It is believed that single-celled organisms capable of photosynthesis, *cyanobacteria*, were in existence by around 2 800 million years ago. Some of the oxygen released into the atmosphere in the process of photosynthesis was converted to ozone, which formed a layer in the stratosphere where it acted as a filter, absorbing much of the ultraviolet radiation from the Sun. As a result, by the time that humans appeared on Earth, and probably by two thousand million years before that, only about half of the total solar ultraviolet radiation, and a much smaller fraction of the short-wave UV-B rays, penetrated to the surface of the planet. Had it not been for this change, life as it exists on land today would not have been possible.

Evidence from ancient rocks indicates that there have been significant changes in the composition of the atmosphere over time. Early in the history of the planet there was a very high concentration of carbon dioxide, and other gases including hydrogen, sulphur dioxide, carbon monoxide, ammonia, methane and hydrogen sulphide were also present. Later, the concentration of carbon dioxide was greatly reduced, and oxygen became abundant. Nitrogen has probably always been present in similar amounts to today's atmosphere.

What is the greenhouse effect?

The atmosphere allows light energy from the sun to penetrate to the Earth's surface, where it is converted to heat energy. This causes the surface of the Earth to warm up, but much of this heat is re-radiated towards the highest parts of the atmosphere and back into space. But some of this outgoing radiation is absorbed by certain gases in the atmosphere, warming the troposphere. This warmed air then re-radiates heat, in all directions. Some of it is directed back into space, while some is reflected back to the surface of the Earth. Because of this effect, the surface of the planet is some 21° C warmer than it would otherwise be. The gases which cause this so-called greenhouse effect are called greenhouse gases.

The natural greenhouse gases include: water vapour (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ozone (O_3). Other gases, like carbon monoxide (CO), sulphur dioxide (SO_2) and nitrogen oxides (NO_x), play an indirect role by influencing the levels of other greenhouse gases.

Figure 2.1 The Greenhouse Effect

That the greenhouse effect exists has been well accepted in scientific circles for over a century. It is a natural phenomenon, and without it our planet would be much too cold to support life as we know it.

Nowadays most people are reasonably familiar with the greenhouse effect. It has been widely publicised, and has figured prominently on many scientific and political agendas over the past twenty or thirty years.

History of concern

Towards the end of the 1890s, Svante Arrhenius in Sweden and P.C. Chamberlain in the United States, both published papers that considered the effects of rising concentrations of carbon dioxide in the atmosphere, suggesting that the continued combustion of coal could lead to global warming.

In the late 1950s it was calculated that about half the carbon dioxide from the burning of fossil fuels was remaining in the atmosphere, and during the 1960s and 1970s, many studies confirmed the potential for climate change due to rising carbon dioxide levels. Various other trace gases were also identified as greenhouse gases. The first multi-dimensional climate models were being developed at this time.

1. It was not until the late 1980s that the issue of long-term climatic warming due to increasing emissions of greenhouse gases came to widespread public notice. Concern about the implications of global warming then led to the development of various international initiatives, including the establishment of the Intergovernmental Panel on Climate Change (IPCC) in 1988, and the Kyoto conference in 1997. These developments are discussed below.

Recent debates

The main debate over recent years has focused on the extent to which human industrial activities, by changing the composition of the Earth's atmosphere through the release of greenhouse gases, are causing, or are likely to cause, global climate change.

At present, the great majority of atmospheric scientists agree that it will not be long before we are living with the effects of an enhanced greenhouse effect resulting from human activities, experiencing warmer temperatures, rising sea levels and significant changes in weather patterns. However, there are still uncertainties about the precise nature of these changes, especially at regional and local levels.

According to the prevailing view, whatever actions might be taken in the future to reduce greenhouse gas emissions, we are already committed to significant climate change due to the greenhouse gases that have already been released into the atmosphere.

There is some disagreement, however, about whether some of the climate changes that have occurred in recent decades are attributable to the increasing concentrations of greenhouse gases in the atmosphere from human activities. This uncertainty has led to confusion among the general public about the urgency of the problem, and has impeded the introduction of policies aimed at effectively reducing greenhouse gas emissions.

The information presented here is based largely on reports of the IPCC and of Australia's CSIRO Division of Atmospheric Science. We recognise that, as in most other areas of environmental concern, there are other viewpoints, and we also appreciate that the scientific establishment is sometimes wrong. On the other hand, it often turns out to be right.

The greenhouse gases produced by human society include the naturally occurring gases carbon dioxide and methane, as well as some synthetic compounds like CFCs and HFCs. The quantities of these gases released by different countries has been closely correlated with material standards of living and economic growth. Thus, the increasing production of greenhouse gases is a function not only of population growth, but also, and more importantly, of our modern economic arrangements and lifestyle patterns, which involve extraordinarily high rates of resource and energy use and technological waste production.

Climate change due to the release of greenhouse gases by human society is an issue that calls for governmental decision-making on a scale and of a kind not seen before in human history. Given the progressive and cumulative nature of the problem, the longer effective action if postponed, the greater the problem will become, and the more difficult it will be to address.

Facts

The concentration of carbon dioxide in the atmosphere has increased over 30% since the beginning of the industrial revolution phase of human history. There is no debate among scientists about this increase, or about its cause. Over the past two decades, the concentration increased on average by 0.4% per year (table 2.1).

<u>Table 2.1</u>

The dramatic increases in global atmospheric concentrations of carbon dioxide, methane and nitrous oxide over the past 1000 years are shown in Figure 2.2, that illustrates the increasing impact of human activities associated with, and following, the industrial revolution. These graphs demonstrate the increasing growth of anthropogenic emissions during the industrial revolution.

<u>Figure 2.2</u>

The global average surface temperature has increased during the 20th century by approximately 0.6°C . Temperatures in Australia have risen by 0.5-.9C over this period, on average higher than global mean trends. Globally, the 1990s have been the warmest decade, with 1998 being the warmest year in the instrumental record. Longer term observations from tree rings, corals and ice cores suggest that the rate of warming during the 20th century was greater than that seen in any century of the past 1000 years, and the trend is continuing (figure 2.3).

<u>Figure 2.3</u>

Corresponding with the increase in global average surface temperatures, there has been a general decrease in snow cover and ice extent around the world. Observations in the Northern hemisphere suggest that there has been a diminution of 10% in the extent of snow cover since the 1960s. The extent of seasonal sea-ice has also decreased by between 10-15% over the past 100 years and mountain glaciers in non-polar regions have retreated considerably.

The past century also experienced an increase in average sea levels around the globe in the order of 0.1 to 0.2 metres. Sea level measurements in the Australasian region reflect this general mean trend, and appear to have risen about 2mm per year over the past 50 years. Data indicate that there have been significant increases in global ocean heat content over the past 50 years since detailed measurements became available.

Predictions

In making predictions about future changes in the climate and other effects resulting from changes in the contents of the atmosphere, it is necessary first to estimate future emissions and eventual atmospheric concentrations of the relevant greenhouse gases, based on knowledge of the sources and sinks of these gases. These projections can then be used in climatic computer models to estimate global and regional responses to these changes globally and regionally.

A range of climate models and climate change scenarios have been developed, most recently by the IPCC, and by CSIRO in Australia. The scenarios project future climatic conditions based on different estimations of greenhouse gas emissions taking account of a range of assumptions with respect to economic growth, emissions controls, energy availability and use, patterns of agriculture and land use, the use of halocarbons and CFCs and levels of population.

Globally, average surface temperature is projected to increase by 1.4 to 5.8C (*format)* by the year 2100. This rate of increase in temperature is greater than any seen in the last 10 000 years.

In regional scenarios developed by CSIRO, it is projected that by 2030 Australia will experience warming in the order of 0.4 to 1.4C in inland areas, 0.3 to 1.0C in northern coastal areas, and 0.3 to 1.3C in southern coastal areas.

All global models predict an increase in the frequency of high temperatures coupled with a decrease in the frequency of extremely low temperatures. In addition, precipitation will be affected, with projected increases in high rainfall events over the next century. Some regions may experience more severe floods and droughts, while in other areas these extreme weather events may be reduced. There is greater uncertainty about the extent to which some other extreme weather events – like cyclones, thunderstorms and tornadoes – will be affected by increasing global temperatures.

It is projected that snow cover and sea-ice extent will continue to decrease over the coming century in northern regions of the world, along with the widespread retreat of glaciers and icecaps. However, it is thought possible that the Antarctic ice sheet may gain mass due to an increase in precipitation.

The loss of mass from glaciers and icecaps around the world, as well as the increased thermal expansion of oceans in response to higher average temperatures, are predicted to contribute to an overall increase in global mean sea level in the range of 0.09 to 0.88 metres between 1990 and 2100.

Even if concentrations of greenhouse gases could be stabilised by 2100, it is likely that global temperature would keep rising beyond that time due to thermal inertia of oceans and the continued presence of emissions in the atmosphere. However, the lower the level at which emissions are stabilised, the less severe will be the total temperature change.

It is necessary, however, to emphasize that, while the great majority of climate scientists agree that global warming is likely to take place for the reasons discussed above, there is much uncertainty about the actual degree of temperature change. This is because the situation really is extraordinarily complicated. For example, some recent evidence suggests that an increase in certain human-induced aerosols in the atmosphere may be causing a decrease in solar radiation reaching the Earth's surface, resulting in a certain cooling effect and a reduction in the rates of evaporation of water.

Given the complex nature of ecosystem interactions, it is very difficult to predict how they will be affected by long-term climatic variations. However, because the rate of climatic change is projected to be greater than the biota have previously experienced, it is likely that the impacts will be very significant. The subsequent environmental changes may well be beyond the adaptive capacity ability of some species.

Soil moisture levels are likely to be affected by changes in temperature and precipitation, with disruption of established water and nutrient cycles. The climatic changes may also affect plant productivity and species interactions, such as competition, predation and parasitism. Likely increases in the occurrence of fire and outbreaks of insects would have further impacts on ecosystems.

Human health and wellbeing will also be significantly affected by climate change. It is likely that a greater frequency of high temperature events will result in higher levels of heat stress mortality across populations. Warmer temperatures will also extend the range of disease-carrying vectors, like mosquitoes, exposing greater numbers of populations to tropical vector-borne diseases such as malaria and dengue.

Rising sea levels will threaten the homes and livelihoods of millions of people living in fertile, densely populated coastal areas at low altitudes, for instance in Bangladesh and the South Pacific Islands. Changes in precipitation could place further pressures on what are already perceived to be limited and stressed global water resources.

Significant impacts on agricultural production are predicted. Any increase in crop production due to higher CO_2 levels will be offset by greater variability in precipitation combined, in some regions, with decreased rainfall, and the limiting effects of increased temperatures.

An argument put forth by the business-as-usual school of thought is that increasing global temperature will be a good thing, at least better than global cooling, and that the enhanced greenhouse effect may be protecting us from the onset of another ice age. A contrary viewpoint is that if fossil fuels really have the potential to prevent another ice age – then surely we should be saving them up until there is clear evidence that the planet is, in fact, entering such an ice age.

Action

The concern expressed by scientists about the enhanced greenhouse effect over the past couple of decades has resulted in a considerable amount of discussion and debate internationally. One of the most significant developments was the establishment in 1988 by the United Nations Environment Program and the World Meteorological Organisation of the *Intergovernmental Panel on Climate Change* (IPCC). Its role is to assess information related to climate change issues and to formulate realistic response strategies for the management of climate change issues.

Increased awareness of potential climate change around the world, and the realisation that this is an issue of global dimensions, also led to the development of a global treaty to address the problem of climate change, the United Nations Framework Convention on Climate Change, which was signed by 155 States at the Rio Earth Summit in 1992, and entered into force in 1994. It provides the overall policy framework for addressing the climate change issue. The ultimate goal of the Framework Convention on Climate Change is to:

> 'achieve....stabilisation of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate

system...Such a level should be achieved within a timeframe sufficient.....to enable economic development to proceed in a sustainable manner.'

Signatory parties are committed to taking steps to achieve this objective under the Convention. Since developed countries have been largely responsible for past and current emissions, some of them have agreed to take the lead in stabilising and reducing emissions. Developing countries are also committed to taking action, but this will depend on the provision of assistance by developing countries. Action to be taken by all parties includes the provision of information and promotion of educational programs about climate change, as well as the adoption of policies and measures that aim to reduce emissions of greenhouse gases.

The Framework Convention provided for signatories to meet annually to discuss and review the latest in climate change science, and assess the adequacy of the policy response at a series of Conferences of the Parties (COP). These meetings led to negotiations aimed at strengthening commitments to the Framework Convention, resulting in the development of the Kyoto Protocol. The text of the Kyoto Protocol was agreed to at the third COP in 1997. The most important feature of the protocol is the emissions targets for Annex 1 (OECD and Eastern European) countries. These parties have agreed to reduce aggregate CO_2 emissions by 5.2% of 1990 levels by 2008-2012. The Protocol allows for specific targets to be set for individual countries that takes into account differing economic circumstances and capacity for change, and also includes several flexibility mechanisms along with options for carbon sequestration

The pact could not come into force until it was ratified by countries accounting for at least 55 per cent of the greenhouse gas emissions of developed nations. It finally became law in February 2005 after eventual ratification by Russia. Australia and the United States of America have so far refused to ratify the treaty.

Another important development internationally has been the Montreal Protocol on Substances that Deplete the Ozone Layer of 1992, which aims to control emissions of CFCs, which contribute to the enhanced greenhouse effect as well as depleting the ozone layer.

An interesting alternative plan for reducing carbon emissions has recently been proposed. It is known as the 'contraction and convergence, or 'C and C'. Essentially, this proposal suggests that all countries aim for the same rate of carbon emissions on a per capita basis – say 0.3 tonnes per year (the average today is about one tonne per year per person). This would mean a very substantial drop in carbon dioxide emissions in the developed countries, but would allow an increase in some developing regions.

Finally, reference must be made to the proposal that the carbon dioxide produced, for example, in coal or petroleum-powered electricity generating plants, should be sequestered below ground. The idea is that the CO_2 would be separated and then compressed to a dense 'supercritical state'. If this material is injected underground, at a depth of 800m or more, it will remain in that dense state for thousands of years or longer. Proponents of this idea believe that the technology is available to do this, although other scientists are doubtful about its practicability.

Australia

Australia has an unusual emissions profile in comparison to other industrialised nations. While this country is a relatively small producer of greenhouse gases, accounting for only 1.4% of total global emissions, our emissions per capita rank third amongst all nations. This has been attributed to the abundance of fossil fuel resources in Australia which has influenced the Australian economy and trade profile, and to our high dependence on fossil fuel based transport.

While energy production and use is a major source of greenhouse gases, accounting for almost 65% of our total emissions, non-energy sectors are more significant in the Australian inventory than for most other OECD countries. The agricultural sector produced significantly larger amounts of greenhouse gases than in other countries, associated with an unusually large proportion of methane, a more potent greenhouse gas than CO_2 in the national emissions profile. Nevertheless, CO_2 still dominates total emissions. Another distinctive characteristic of Australia's emissions profile is that certain activities in the forestry sector, such as clearing, are sources of greenhouse gases rather than sinks that actively take up and store CO_2. ***It has been estimated that in 1990 carbon dioxide emissions resulting from forest clearance amounted to 156 million tonnes, or 27.3 per cent of this country's nett emissions: and the rate of clearance has increase considerably since that time.***

Despite all current measures, and being signatory to the Framework Convention on Climate Change, Australia's total emissions are projected to increase by 18% from 1990 to 2010. At this stage, the Australian Government has refused to ratify the Kyoto Protocol, despite increasing international and domestic pressure. In a move that is seen by environmentalists as further evidence the Government is backing away from the issue, it abandoned research into an emissions trading scheme which under the Protocol could allow industries to invest in so-called carbon sink projects, such as forests, to offset greenhouse gas output.

Summary

Globally, the situation can be summarised as follows:

1. Human technological activities involving the combustion of fossil fuels are resulting in progressive increase in the concentration of carbon dioxide in the atmosphere of this planet. The concentration is still increasing, at a rate of 0.4% per year. The concentration of two other greenhouse gases, methane and the CFCs, which were increasing until recently, seems to have stabilised.
2. Most atmospheric scientists, including members of Australia's CSIRO Division of Atmospheric Science, predict that this increase in carbon dioxide in the atmosphere will result in progressive global warming, with uncertain consequences for humankind.
3. An argument put forth by the business-as-usual school of thought is that increasing global temperature will be a good thing, at least better than global cooling, and that the enhanced greenhouse effect may be protecting us from the onset of another ice age. A contrary viewpoint is that if fossil fuels really have the potential to prevent another ice age – then surely we should be saving them up until there is clear evidence that the planet is, in fact, entering such an ice age.