Module 4: Energy

Enhanced Greenhouse Effect, Global Warming, Climate Change

(*Not required for the HSC but included here because there is currently great interest in the topic.*)

These three terms refer more or less to the same thing – the increase in average global temperature that has been observed in recent decades and its consequences in terms of changes in long-term rainfall, severe storm patterns, rising ocean levels and melting of polar ice-caps – increases and changes that are attributed to increased concentrations of carbon dioxide and a few other gases in the atmosphere mainly due to human activities. It was originally called the greenhouse effect because the Earth's atmosphere acts like the glass of a greenhouse – it lets energy (sunlight) in but slows down the escape of energy (in the form of heat) to the outside and in so doing causes the temperature in the greenhouse or on the Earth's surface to be considerably higher than it otherwise would be. For well over a hundred years scientists have known that carbon dioxide in the atmosphere was keeping global temperatures about 30^{o} higher than they would otherwise have been and so was providing a hospitable environment for all current life forms. In other words the natural greenhouse effect is a 'good thing'.

Since the Industrial Revolution (that is, since about 1750) when societies started burning coal in increasingly large quantities, the carbon dioxide concentration in the atmosphere has been increasing. Since about the 1960s scientists have been predicting that global temperatures would increase as a consequence of this and since at least the 1980s clear evidence of small but significant increases have been observed. This extra warming of the Earth by these increasing concentrations of carbon dioxide from human activity is called the *enhanced* greenhouse effect.

Today the term greenhouse effect or enhanced greenhouse effect is less commonly used; instead the effect is generally referred to as global warming or climate change. The latter two terms allow for the possibility that some of the effect may be a natural phenomenon.

How the greenhouse effect works

In order for the Earth, or any body for that matter, to maintain a fairly constant temperature, the flow of energy out must equal the flow of energy in. All bodies emit radiation. The Sun (at 6000 K) is a very hot body. The radiation it emits is mainly in the visible and ultraviolet region. The Earth is a much colder body (288 K); the radiation it emits is in the infra-red region (longer wavelength than visible light).

The major components of the atmosphere (nitrogen, oxygen, argon, water vapour, carbon dioxide) do not absorb long-wavelength u.v. or visible light. Therefore solar energy passes through the atmosphere, gets absorbed by the Earth’s surface, and so warms it up. The atmosphere impedes the flow of energy from the Earth to outer space, because it contains some gases which can absorb infra-red radiation, notably carbon dioxide and water vapour. As infra-red radiation passes from the Earth’s surface through the atmosphere, some of it is absorbed by carbon dioxide and water. These substances re-radiate some of this energy back to Earth. Figure 1 illustrates. The net effect is that carbon dioxide and water vapour slow down the flow of heat energy from the Earth. This causes the Earth’s surface temperature to be higher than it would otherwise be. If there were no atmosphere, the mean surface temperature of the Earth would be about –18°C. With the atmosphere present the mean is about 15°C. This natural warming is called the **greenhouse effect**. It is highly beneficial, because without it Earth would be too cold to support life as we know it.

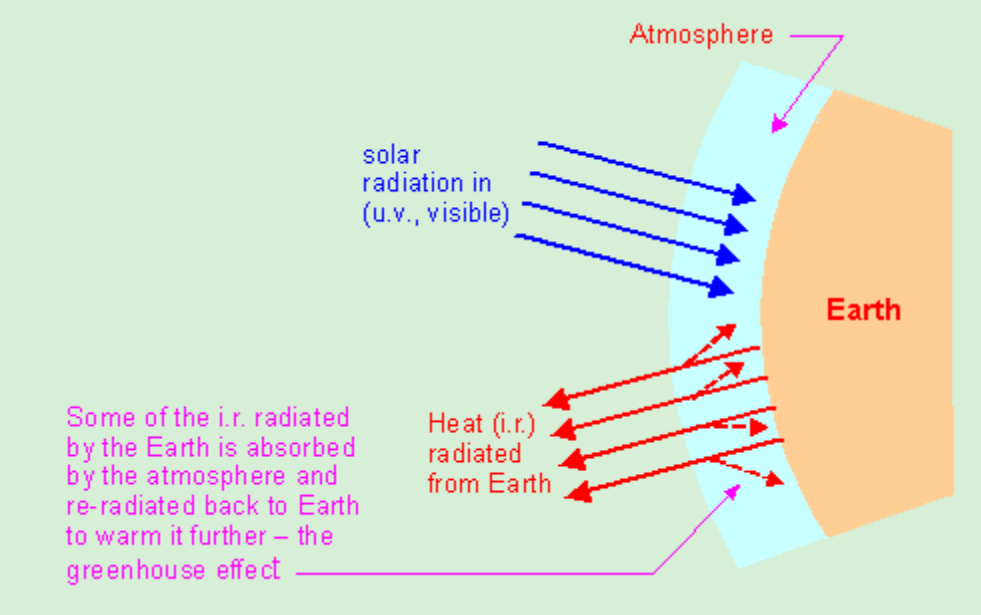

Figure 1. How the greenhouse effect works

However human activities are increasing the concentration of carbon dioxide (and some other gases) in the atmosphere and this is leading to further increases in global temperatures. This is called the **enhanced greenhouse effect** or sometimes **global warming** or **climate change.**

Main causes and effects of global warming

Burning fossil fuels, such as coal, oil and natural gas, releases carbon dioxide to the atmosphere. The huge and increasing quantities of fossil fuels being burnt worldwide for energy generation are increasing the concentration of carbon dioxide in the atmosphere. Deforestation (for timber) or land clearing (for growing crops or pastures for stock) is also increasing the concentration of carbon dioxide in the atmosphere, first because the burning or decay of the forest residues or cleared scrub releases carbon dioxide and secondly because the crops or pastures absorb less carbon dioxide than the forests or scrub they replaced. Consequently atmospheric carbon dioxide concentration has increased from about 280 ppm (parts per million) or 0.028% at the middle of the eighteenth century to about 380 ppm today. Today CO_2 is increasing by about 2 ppm per year.

There is evidence that over the past 100 years the mean surface temperature of the Earth has increased by about 1.0°C and that sea levels have risen about 15 cm. There have also been changes in rainfall patterns, melting of polar ice caps and glaciers and increased frequency of severe weather events such as storms, floods and droughts.

Figures 2, 3 and 4 show how atmospheric carbon dioxide concentrations, global temperatures and ocean levels have changed in recent times.

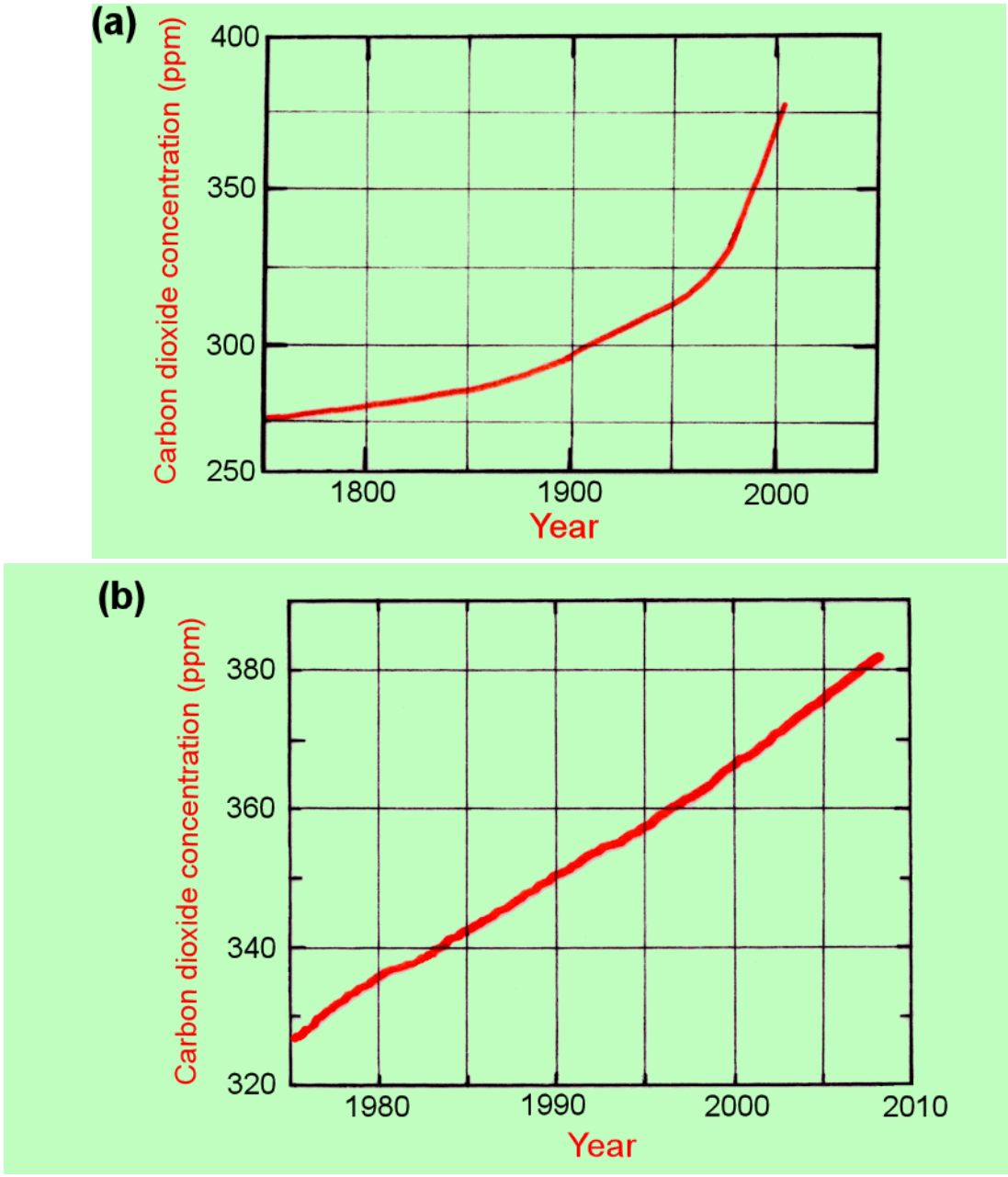

Figure 2. Atmospheric concentrations of carbon dioxide (a) since the industrial revolution and (b) over the last 20 years

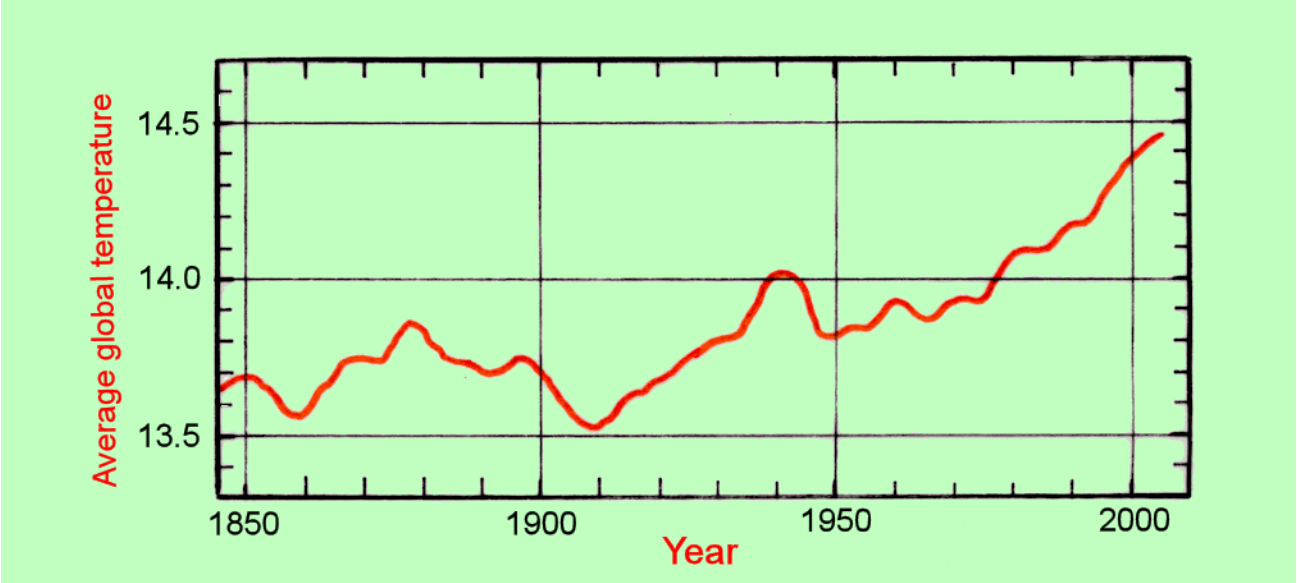

Figure 3. Variation in average global temperature over the past 150 years

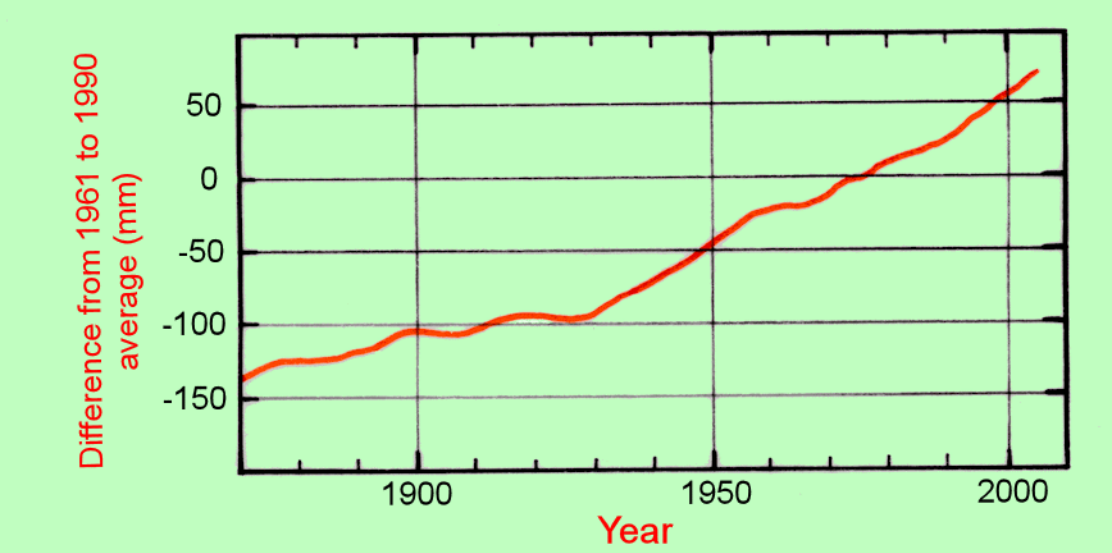

Figure 4 The rise in average ocean levels over the past 150 years

Gases that contribute to this warming effect are called **greenhouse gases.** Carbon dioxide is the main greenhouse gas.

Other greenhouse gases

Methane, nitrous oxide, chlorofluorocarbons (CFCs) and other compounds containing carbon and halogens are also greenhouse gases, meaning that they too absorb the infrared radiation the Earth emits and re-radiate some of it back to Earth and so add to global warming. Human activity has increased the concentrations of these gases also – methane from the increasing cattle, sheep and pig populations and from mining or extracting fossil fuels, nitrous oxide from increased fertiliser use and CFCs from their use in refrigeration, foam plastics manufacture and so on (though CFC releases are now stabilising and will

fall because of efforts to control the ozone hole problem, *CCHSC* pages 247-59). The combined effect of all these gases is currently about 20% of that due to carbon dioxide.

Atmospheric scientists often talk about the **equivalent carbon dioxide concentration** in the atmosphere, ppm CO_2–eq or just ppm CO_2–e, meaning the concentration of carbon dioxide that would have the same global warming effect as all the greenhouse gases present in the atmosphere. While currently the actual concentration of CO_2 is 380 ppm, the *equivalent* concentration is approximately 455 ppm. Newspaper reports often fail to distinguish between these two concentrations and this can lead to confusion.

An indication of the sensitivity of climate change to increased greenhouse gas emissions is this: a doubling of the equivalent carbon dioxide concentration in the atmosphere would increase global temperature by about 3^{o}C. This doubling will occur by 2030 without a concerted world effort to cut emissions.

Predicting future effects

While it is not too difficult to measure the increases in concentrations of greenhouse gases in the atmosphere over time, it is quite hard to measure the small changes in climate produced by these increases, particularly as there is usually a time lag between concentration increases and climate change and as there are other factors that influence climate. It is also very hard to predict future climate changes resulting from increasing concentrations of greenhouse gases. Scientists use elaborate computer modelling to do this. World wide there are many groups of atmospheric scientists doing this modelling using a great variety of programs and approaches. To assess the work of the vast number of experts studying climate change the United Nations has set up the Intergovernmental Panel on Climate Change, IPCC. This panel of experts from all around the world meets periodically to evaluate and assess the findings of the various researchers and to prepare summary reports of the main findings of the scientists for governments to use for developing national and international policies to address the problems.

The fourth report of the IPCC in February 2007 concluded that over the next few decades global temperatures are expected to rise by about 0.2^{o}C per decade and sea levels by about 3 cm per decade. Even if the atmospheric concentrations of greenhouse gases remain constant at 2000 levels there will be an increase of 0.1^{o}C per decade (because temperature rise lags behind greenhouse gas concentrations).

Longer term predictions depend upon how fast world populations and economies grow, how quickly countries move away from fossil fuels and what technological innovations become available. Best estimates are that by the year 2100 global temperature will rise by between 4^{o}C (if there is strong economic growth and continued dominance of using fossil fuels to generate energy) and 2.4^{o}C (if there is only modest economic growth with major shifts away from fossil fuels) and that sea levels will rise between 0.3 and 0.4 m.

Consequences of global warming

The main effects of global warming are:

- Many ecosystems will be altered and many species threatened with extinction
- There will be changes in rainfall patterns (more rain in some regions, less in others)
- Agricultural productivity will be changed
- There will be erosion of coastlines
- Habitats of millions of people living on river deltas or flood plains or low islands will be severely damaged and mass migration of populations will be necessary
- Infrastructure in coastal cities and towns will be damaged

- There will be detrimental health effects because of heat waves and of the spread of water-born diseases
- Urban water supplies will become stressed

In Australia

By 2020 the Great Barrier Reef will have been seriously damaged .
By 2030 there will be water supply problems in the major cities in the south and east (including Brisbane, Sydney, Canberra, Melbourne), there will be a serious decline in irrigation agriculture in the Murray-Darling Basin and significant disruptions to many other forms of agriculture throughout the country. Forestry production will be in decline because of more frequent droughts and severe bushfires.
By 2050 many coastal towns and resorts will be suffering damage from severe storms, regular flooding and sea water inundation.

Feedback loops

In global warming contexts there are serious concerns about what are called positive feedback loops. These are situations in which a rise in global temperature causes an effect and that effect in turn causes a further rise in temperature and so aggravates the problem quite significantly. Two of the most important feedback loops are

1. An increase in ocean temperature means that the ocean can dissolve less carbon dioxide (remember gas solubility decreases as temperature rises, *CCHSC* pages 426-7). Much of the carbon dioxide released into the atmosphere is dissolved by the ocean. If the ocean dissolves less, then the atmospheric concentration of carbon dioxide increases more rapidly and so there is more warming.
2. An increase in global temperature causes the polar ice caps to melt. The polar ice caps reflect back into space much of the solar energy (u.v and visible light) that falls upon them. If there is less ice, then less solar energy is reflected, meaning more is absorbed (ice reflects most of the solar energy that falls on it, water absorbs most of the solar radiation that falls on it) and so the Earth heats up more quickly and hence the ice melts more rapidly and so warming accelerates.

Positive feedback loops could lead to what are called **tipping points**, times when the positive feedback becomes so strong that it keeps forcing temperatures up regardless of what we do to try to stop it: global warming would then become irreversible. The possibility of a tipping point being reached within a few decades is most worrying.

The cure

Until recently it was considered impractical to remove carbon dioxide chemically or mechanically from the atmosphere or from the emissions from power stations, factories or vehicles. Therefore our major method of combating global warming has to be to use less fossil fuel. This means

- developing more efficient cars, industrial processes and appliances (so that the same useful work can be obtained from less energy – that is by burning less fossil fuel)
- designing houses and other buildings so that they require less heating, cooling and lighting (such as using energy-efficient light bulbs)
- developing alternative sources of energy that do not release carbon dioxide (solar, wind, hot rocks, tidal, biomass etc) or as an interim measure using natural gas instead of coal to generate electricity since it releases about 50% less carbon dioxide per unit of energy.
- using nuclear energy to generate electricity, but more on this later
- reducing the amount of deforestation and land clearing which is proceeding at great rates in parts of South East Asia and South America and which is still going on in Queensland and NSW though at much smaller rates that in the 1990s

- planting many more trees which in the short term is effective in that growing trees absorb much carbon dioxide and which will help in the long term if the timber of the trees is used for housing and construction and not let decay back to carbon dioxide.
- modifying our lifestyles in order to lower our overall energy demands (for example by driving smaller cars shorter distances per year, using bicycles or walking whenever possible, buying fewer consumer goods and keeping them longer, repairing, re-using and recycling furniture, appliances, entertainment systems, computers and clothing instead of throwing them away and buying new ones, avoiding energy-intensive leisure activities such as water skiing, indoor gymnasiums and overseas travel; many people who are conscious of their energy consumption in the forms of electricity, gas and petrol often overlook the fact that there is a very high energy component in the manufacture of cars, household goods, entertainment systems, clothing etc).

The last approach is the one least talked about because it does not appeal to most people and it would have serious consequences for national and global economies; it would dramatically slow down economic growth which currently seems essential for the economic wellbeing of nations.

Currently there is considerable talk about a process called **carbon capture and sequestration**. This involves trapping carbon dioxide out of the effluent gases from power stations, transporting it to suitable sites (such as exhausted natural gas wells) and storing it at very high pressure in porous rock deep underground where it is claimed it will remain indefinitely. While some encouraging results have been reported, the complete process has not been demonstrated on a commercial scale and many environmental scientists remain deeply sceptical of it and are yet to convinced that it could be done without using more energy than was being produced by the power station. Carbon dioxide is only about 10% of the exhaust gas of power stations. Sequestration is the basis for the **clean coal technology** that politicians and the fossil fuel interest groups talk about.

Bringing this about

The ways of bringing these cures about are:

1. Persuade (educate) and/or subsidise commerce, industry and people to make and buy more energy-efficient machinery and appliances and to learn to live in more energy-economical ways.
2. Increase the cost of energy derived from fossil fuels by introducing some form of carbon tax (such as so many dollars per tonne of carbon dioxide emitted, or an emissions trading scheme – see below) and by so doing making energy derived from non-fossil-fuel sources (currently more expensive) more price competitive.
3. Pay government subsidies for research into alternative energy sources to reduce costs and increase availability of non-fossil-fuel energy.

The only way to solve or alleviate the global warming problem is by concerted international action. With most other forms of pollution localised action solves the problem. If a region or nation is suffering from particulate and sulfur dioxide pollution from heavy industry, then controls on industrial effluents will fix it. If a city suffers from photochemical smog, then controls on exhausts from motor cars solve the problem. However when the pollutant has no immediate local effect but disperses through the whole atmosphere and so affects the whole world, then local action will not fix it: the whole world has to take action. This was the case with the ozone hole problem (release of CFCs into the atmosphere, *CCHSC* pages 247-59); concerted action by most nations through the Montreal Protocol and subsequent agreements is seeing the problem being contained and gradually cured.

Global warming is another problem that requires concerted international action. There have been several international ‘agreements’ aimed at limiting greenhouse emissions.

International conferences

The first international response to global warming was the Toronto Conference of 1988 leading to the **Hague Declaration of 1989**; this was an undertaking by the signatory nations to reduce carbon dioxide emissions to 80% of their 1988 levels by the year 2005. Australia signed it, but the USA, UK, China and the USSR (who together produce 60% of global carbon dioxide emissions) did not. No nation, signatory or not, appears to have seriously tried to implement it. (Though Australia signed it, we virtually ignored it!)

In June 1992 the United Nations Conference on Environment and Development was held in Rio de Janeiro; it is widely referred to as the **1992 Earth Summit**. This was the largest gathering of heads of government in history and the most widely publicised conference on the environment ever. It produced, among other equally important documents, the Framework Convention on Climate Change which despite noble sounding sentiments contained no definite timetable for emission reductions. Australia signed this framework agreement. There were follow-up conferences (of little consequence) in Berlin in 1995 and in Geneva in 1996.

The first real attempt to introduce specific limits for greenhouse emissions was the **1997 Kyoto Conference** (in Japan). It set targets for specific countries. 'More developed' countries were to reduce their annual greenhouse gas emissions below their 1990 levels by amounts varying from 7% to zero (depending on the effectiveness of their special pleadings). 'Less developed' countries (including China and India) were to be 'encouraged' to reduce their emissions but without specific targets. The agreement was to run until 2012 when a new (hopefully more effective) one would start. On the basis of the Kyoto targets, atmospheric equivalent carbon dioxide concentration was expected to increase (from 1990 levels) by about 10% instead of the 11 or 12% expected without the agreement. Not a great improvement! In fact the concentration has increased by about 20% (up to 2008).

Sufficient nations signed up to the Kyoto agreement (but not the USA or Australia) for it to come into force.

In **Bali in December 2007** there was a conference to discuss strategies for a post Kyoto agreement (beyond 2012). This meeting set an overall guideline of a 25% to 40% cut in emissions by 2020. A conference is scheduled for Copenhagen in 2009 to develop the details of a new agreement.

The two main principles underlying the Kyoto agreement (and probably future ones) are
1. the polluter pays and
2. the ability to pay.
'More developed' countries recognised that they had been primarily responsible for the increase in atmospheric carbon dioxide concentration from 280 ppm in the pre-industrial era to the 350 ppm of the 1990s so the major burden in reducing greenhouse gas emissions should fall upon them. In addition the countries that had contributed least to the problem were the ones least able to afford to fix it up. Hence the treatment of 'less developed' countries in the agreement. By adamantly refusing to sign Kyoto until China and India signed, the Howard government in Australia made it clear that it did not accept the polluter pays principle.

However the rapid economic growth of China and India in the last two decades probably means that they (and possibly other developing countries) will have to be included in any future agreement.

If there are to be limits on greenhouse gas emissions, then what is a fair basis for allocating them? At Kyoto the negotiations were mainly about arbitrary cuts – what nations were prepared to do and what they could afford. Since then a general principle has been emerging, that each person on the planet is entitled to emit the same amount of greenhouse gas. It is now emerging that the steps in developing future global policies on restricting greenhouse gas emissions should be:

- Determine what is an acceptable level of global warming over say the rest of this century (2 or 3^{o}C?).

- Use this to determine what the equivalent concentration of carbon dioxide in the atmosphere can rise to (450 or 550 ppm CO_2–eq?)
- Calculate the annual quantity of greenhouse gas that the world can emit into the atmosphere without exceeding this concentration (probably while having to allow some overshoot of the target concentration in the short term if it is 450 ppm before it settles down to the set value).
- Allocate a quota of this total to each nation of the world based upon the principle of equal emission per person, current population and expected population changes.
- Allow emissions trading; that is, allow nations that currently emit less than their quota to sell some of their quota (on an annual basis) to nations that are exceeding their quota. Buying some of other nations' quotas will supplement direct emission reduction strategies by nations that have to reduce their emissions (such as Australia, Canada and the USA) and will provide additional income to the selling nations (generally the less developed ones).

The conference planned for Copenhagen in December 2009 will consider these matters.

Australia's approach

Until recently Australian governments (both Labor and Liberal/National) have not been very supportive of international actions to curb greenhouse gas emissions.

In 1981 the Office of National Assessment, one of Australia's key intelligence-gathering bodies, warned of possible damage to Australia's energy exports (mainly coal) if the nations of the world decided to reduce greenhouse gas emissions. Although the report was not published, its warning has been a prime concern of governments of all persuasions ever since.

In 1989 after the Hague Declaration, state governments (and later the federal government) undertook to reduce greenhouse gas emissions by 20% below 1988 levels by 2005. A few voluntary schemes were introduced but green house gas emissions continued to increase. Federal and state governments were supportive of the Rio Conference (Earth Summit) of 1992 but did little to implement its goals.

Australia participated in the 1997 Kyoto conference, and after special pleading, was allowed to maintain its emissions at 1995 levels (one of very few nations allowed to increase its emissions above 1990 levels). But more importantly at the last minute in the negotiations the Australian delegation managed to force into the agreement a clause that would allow nations to use reductions in emissions resulting from changes in land use to offset actual emissions. The Australian delegation knew that 1990 had been a year of extremely high land clearing and that there had been a steady decline in land clearing ever since. This clause, which became known as the Australia clause, was of no relevance to the other 'more developed' nations because land clearing was not an issue with them and the 'less developed' nations that were engaged in extensive land clearing were not subject to mandatory limits anyway.

Despite these favourable treatments the Howard government in 1998 decided not to ratify the Kyoto agreement unless the USA ratified it; the USA refused to ratify it.

The Australia clause has had great significance for the emissions debate in Australia. The government maintained that from 1998 to 2007 Australia was meeting its Kyoto target, while environmentalists claimed that it was exceeding them by large amounts. Both claims are correct! Our actual greenhouse gas emissions from non-land use sources have increased by 30% since 1990, but because the amounts of land clearing (and their associated CO_2 emissions) have decreased significantly from the very high peak of 1990 the net increase is within the 8% increase allowed by the Kyoto agreement.

In 1997 the federal government set up the Australian Greenhouse Office to oversee efforts to reduce emissions and to monitor progress of various voluntary abatement schemes. In 2000 the Australian

Greenhouse Office proposed Mandatory Renewable Energy Targets for electricity providers. However by the time the legislation had passed through parliament they had been watered down from 2% (over the then existing renewables) to just 1%.

Most ministers in the Howard government, at least until 2006, were greenhouse sceptics, meaning that they did not believe that global warming was being caused by human activity. Hence they were reluctant to take any action that could conceivably disadvantage Australian industry, particularly the fossil fuel industry. This was partly because they (and the Hawke-Keating government before them) were heavily influenced by an effective lobby group made up of representatives of the coal, oil, cement, aluminium, mining and electricity industries. Some members of this group unashamedly described themselves as the 'greenhouse mafia'. The aim was to sabotage any government efforts at restricting greenhouse gas emissions. Voters generally were not particularly upset by government inaction, apart from small environmental groups.

However things changed quite dramatically in the second half of 2006.

The devastating drought in the Eastern states was dragging on into its seventh year, the Stern Report (by a British economist) was published and claimed that the economic cost of reducing greenhouse gas emissions would be less than the costs of coping with the consequences of global warming, a movie *An Inconvenient Truth* by a former US vice-president Al Gore presented in graphic form and in clear and simple language a convincing case for the reality and dangers of global warming, and finally in October there were two record hot days. People at last started believing that global warming was real and began to accept the need for action. By year's end opinion polls showed for the first time a majority of voters in favour of reducing greenhouse gas emissions.

The Labor Party was quick to adopt policies for cutting greenhouse gas emissions and went to the 2007 election with ambitious plans for doing this, including ratifying the Kyoto agreement, a long term goal of reducing greenhouse gas emissions by 60% by 2050 and an emissions trading scheme (to cut emissions in the short term). By the middle of 2007 even the Howard government was reluctantly accepting the reality of the problem.

The Labor Party won the November 2007 election. The new government immediately ratified the Kyoto agreement (at the December 2007 Bali conference), gave in principle support to the Bali goal of a 60% cut in emissions by 2050 and began plans for an emissions trading scheme to be begin in 2010.

An **emissions trading scheme** is a program which requires industries that emit greenhouse gases to buy a permit to do so. The government sells permits that allow the emission of specified quantities of greenhouse gas over a specified time (say a year or two). The total permits issued restrict the quantity of greenhouse gas emitted to the amount the government decides upon to meet its own or international emission reduction targets. Companies may trade (sell) their permits. If a company decides that it is cheaper to improve its technology and cut its emissions, it can then sell its excess permits to another company that has decided that for it it is cheaper to buy extra permits than update its technology. Although individual citizens emit greenhouse gases in many ways such as by using their motor cars, gas appliances and indirectly by using electricity, they do not need permits; instead the companies that supply the fuel for the cars or the gas or the electricity for the home have to hold permits to cover those emissions. The aim is to increase the cost of fossil-fuel-based energy and so encourage industries to use alternative energy supplies and/or to develop energy-saving processes and persuade ordinary citizens to reduce their energy consumption.

Because such schemes involve increased costs to consumers, they are usually accompanied by programs of subsidies to the more vulnerable groups such as the poor and elderly; these are paid for out of the income the government gets from sale of the permits. In addition the government can use some of the extra income to subsidise industries that it considers may be unduly disadvantaged by such energy cost increases. This particularly applies to export-oriented industries if their trading competitors are not

subject to similar schemes. However caution is needed with subsidies in that they could defeat the whole purpose of the scheme.

During 2007 the Labor state governments at the request of the federal Labor opposition commissioned an economist with strong credentials in climate change policy, Ross Garnaut, to prepare a report on the likely economic consequences for Australia of global warming and to recommend cost-effective ways for Australia to tackle the problem. The **Garnaut Report** was released in September 2008. Its main recommendations were:

1. Australia should support a long-term goal of 450 ppm CO_2–eq and in terms of an international agreement be prepared to cut its greenhouse gas emissions by 25% by 2020 and by 90% by 2050, or if agreement on 450 ppm is not achievable, then support a 550 ppm CO_2–eq goal which would require a 10% reduction in emissions by 2020 and an 80% one by 2050. In the absence of a global agreement Australia should commit to a 5% reduction in emissions by 2020.
2. Australia should set up an emissions trading scheme (along the lines described above) as soon as possible. This was considered preferable to a simple carbon tax (of x dollars per tonne of greenhouse gas emitted) because it could easily be integrated into similar schemes being developed in other parts of the world and it lets the marketplace determine the price instead of it being arbitrarily set by a government.
3. An emissions trading scheme should include compensation for consumers, particularly low income ones, and for trade-exposed emission-intensive industries, that is for industries that rely heavily upon exporting their production, but should be cautious of giving ongoing compensation to industry, particularly electricity suppliers. The report recommends that proceeds from selling permits should be split 50% for compensating consumers, 30% for compensating vulnerable industries and 20% to research into renewable energy sources and/or to fossil energy cleanup.

The government intends to introduce such an emissions trading scheme by 2010, though only for an unconditional 5% emissions reduction with the possibility of going to 15% if an international agreement is forthcoming. Its proposals include much more extensive compensation to industry (including electricity generation) that the Garnaut Report recommends. Environmental groups are disappointed that the government appears to have backed away from its more ambitious pre-election proposals and to be spending a disproportionate amount of its research funds on so-called clean coal technology (described above) at the expense of possibly more promising new energy-generation methods.

Is nuclear energy the answer?

At first sight nuclear energy seems the ideal way of generating electricity without greenhouse gas emissions, because the energy comes from splitting uranium atoms (*CCHSC* page 80) without any production of carbon dioxide. However on closer inspection the case is not so clear-cut. Huge amounts of fossil fuels are needed to mine the uranium ores, extract the uranium from them, then enrich it so it will undergo fission (only the less abundant isotope U-235 does this), fabricate it into suitable fuel rods, build the reactor with adequate safety features for what is a very dangerous process, and provide long-term storage facilities (250 000 years) for the spent fuel rods and/or nuclear wastes. These fossil-fuel energy inputs could well be a significant proportion of the energy produced by the reactor.

Nuclear reactors were first used to generate electricity commercially in the 1950s and 60s and their use steadily expanded through the 1970s and 80s, particularly in the UK, France, the USA, the former Soviet Union and Japan. Two serious reactor accidents, one at Three Mile Island in the USA in 1979, the other at Chernobyl in the former Soviet Union in 1986 dampened enthusiasm for nuclear reactors, along with fears about long-term waste storage (still not solved), low-level radiation leakage, nuclear weapons proliferation (plutonium a by-product of reactors is the key ingredient for making nuclear weapons) and fear of sabotage by terrorists. Very few new reactors were built in the following twenty years. However the seriousness of the global threats from climate change has made many people, even some who opposed

nuclear energy in the 1970s and 80s, wonder if nuclear energy could provide a partial answer to global warming. Were the risks from global warming greater than the risks from nuclear reactors?

In keeping with this growing sentiment the Howard government in 2006 set up a committee to investigate whether nuclear reactors for electricity generation could significantly reduce Australia's greenhouse gas emissions. The committee's conclusions were presented in the **Switkowski Report** in early 2007. It found that twenty nuclear reactors along the Eastern seaboard could produce half the nation's electricity requirements with the release of 25% less greenhouse gas than coal-burning stations. The likelihood of finding sufficient suitable sites without vigorous local opposition is remote. The government did not commit to the proposal. While the population generally was unenthusiastic towards the idea, the government did use it to argue that other nations may find the nuclear option attractive and that therefore Australia should lift the restrictions on uranium exploration and mining that had existed since the 1970s and so allow increased export of uranium. The Labor party concurred with this. Cynics believe that lifting these restrictions was the government's only intention right from the start.

Many experts dispute the finding of the Switkowski Report that nuclear reactors can generate electricity with a 25% reduction in greenhouse gas emissions. The report's calculations were based on using high grade uranium ores which if there is widespread adoption of nuclear energy around the world will soon be used up; if lower grade ores are used the energy saving becomes much less or even zero (it takes more fossil-fuel energy to extract the uranium from low-grade ores). In addition the Switkowski calculations did not include adequate energy costs for long-term storage of wastes nor for the dismantling of reactors at the end of their lifetimes (which at the moment the UK is finding to be prohibitively expensive).

Sources

IPCC Fourth Assessment Report (www.ipcc.ch)
The Garnaut Climate Change Review, Final Report (www.garnautreview.org.au)
Hamilton, Clive, *Scorcher: the dirty politics of climate change*, Black Inc. Agenda, Melbourne, 2007
Caldicott, Helen, *Nuclear Power is not the Answer*, Melbourne University Press, Melbourne, 2006.
Figures 2, 3 and 4 were drawn using data from the above IPCC report.

What is said above about the Australian scene is correct at the time of writing (February 2009). However things could change fairly quickly.