Inside the Greenhouse

The greenhouse effect: what is it, what does it mean to our climate, what does it mean to you?

You've heard of the 'greenhouse' effect - everybody's heard of the greenhouse effect - but do you know what it actually involves, and have you ever considered how it may affect your future? There are many uncertainties about the greenhouse effect, but most scientists believe it could have a significant impact upon our lives over the next several decades. It's worth thinking about what that might mean to you and your family! This feature briefly sets out how the greenhouse effect works, why it's being given so much attention, and what it could mean to you. This feature has been produced by the Department of the Environment, Sports and Territories and CSIRO.

The greenhouse effect

Earth's atmosphere has many remarkable properties. It lets through energy radiated from the sun, but is able to store part of the energy which is reradiated out into space. If it couldnít store this energy, the energy would immediately be lost, and itís estimated the global annual average temperature at the surface would be a chilly -18oC. Instead, itís a life-supporting 15oC!

The Sun's energy reaches the Earth as incoming solar radiation of short wavelengths. Part of this energy is absorbed by the Earthís surface, and then reradiated back at longer wavelengths (infrared radiation or heat). Part of this outgoing infrared radiation gets absorbed by some of the gases that make up our atmosphere. These gases are referred to as greenhouse gases. They absorb and reradiate this outgoing radiation, effectively storing some of the heat in the atmosphere. The process is called the greenhouse effect.

Water vapour is the most significant greenhouse gas and accounts for about 75% of the natural greenhouse effect. Carbon dioxide is the next most significant gas. Both of these gases are naturally occurring components of the atmosphere.

The greenhouse effect is vital to life on our planet as we know it! The enhanced greenhouse effect

If it's a natural process, what's the big worry? It's not the greenhouse effect itself that's the worry. The concern is that human activity is increasing the concentrations of some greenhouse gases in the atmosphere and adding new gases that are very efficient at absorbing heat. The problem is that these additions may enhance the natural greenhouse effect, which may in turn lead to global warming and change the Earth's climate.

The concentrations of greenhouse gases are increasing, and there is very strong evidence available to indicate that these increases are linked to human activity. Scientists have been making direct measurements of various gases in the atmosphere for over 35 years. They have also analysed air bubbles trapped in ice cores taken from Greenland and Antarctica to determine the levels of greenhouse gases over recent centuries, and have recorded notable variations in the levels of greenhouse gases. For example, at the peak of the last Ice Age 18,000 years ago, CO2 levels were roughly 25% lower than pre-industrial levels. Since about 1850, they've risen by a further 25%.

While there is no doubt that levels of greenhouse gas have increased significantly over recent years, there is uncertainty as to what future levels of greenhouse gas will be. Also, estimating the possible effect that these future levels may have on Earth's climate is a very complex process.

Greenhouse gases in the future

The greenhouse gas that the scientists are most concerned about is carbon dioxide (CO2). By burning fossil fuels (like oil and coal, both carbon-based materials; and cutting down and burning forests, wood is carbon based), we are adding significant quantities of CO2 to the atmosphere. Scientists are also concerned about levels of methane, nitrous oxide, ozone and chlorofluorocarbons (see the Gas Table). They do not include water vapour because our emissions of this gas are so small compared to the total amount of water vapour in the atmosphere, that it's not believed that human activity can directly or significantly alter the levels of water vapour in the atmosphere. (However, changes in levels of water vapour in response to climate change may be an important part of climate change as a whole.)

Predicting future greenhouse gas concentrations in the atmosphere is difficult because so many different factors are involved, and scientists are still uncertain as to how some of these factors interact. Future concentrations of greenhouse gases will largely depend upon the quantity of gases emitted into the atmosphere, and the rate at which theyíre removed. Of course, the removal processes are different for each gas.

Emission rates are dependent upon such things as the rate of human population growth, technological change, fossil fuel consumption (per head of population), deforestation and reforestation. It will also depend on the success of international efforts to curb emissions. To make estimations of the quantities of greenhouse gases that will be generated, scientists have made assumptions about all these factors. Put together, these estimates are called emission scenarios, which are really projections of emissions based on expected future trends.

One that is commonly used is called the business-as-usual scenario. It assumes that the world population will continue to grow at much the same rate as today, and that we will continue to use resources in much the same way - basically, business as usual.

As you can see, estimating future greenhouse gas concentrations is not a simple task. It's further complicated by the fact that the different greenhouse gases vary in their ability to intercept radiation. Some trap more heat than others. So, when developing scenarios of future climate, scientists try and combine the effects of all the gases together. They talk about a time in the future when the combined effect of all the greenhouse gases in the atmosphere is equivalent to a doubling of CO2. One well-known estimate is for this to occur by the year 2030 (though this estimate is under constant review).

At present, scientists' best estimate is that there will be the equivalent of a doubling of CO2 by 2030. These changes in the Earth's atmosphere will cause the planet's average surface temperature to rise by between 0.2 - 0.5oC per decade. By 2030, that would mean an average increase of 0.7 - 1.0oC on 1990 temperatures. Now, that might not sound like a big difference, but it has the potential to change many aspects of our lives.

Climate change and our future

When discussing how climate change may affect our lives, it's important to distinguish between weather and climate. Weather is the state of the atmosphere over a short time, ranging from minutes to days. Climate can be considered to be the 'average weather', usually considered over several decades. Long term records show the climate has varied naturally on time scales of decades to millions of years.

Our whole community is planned with the climate in mind. Dams, sewers, towns, cities and farms are designed to withstand the worst weather (extremes of climate) that are likely to strike over the life span of any particular project.

Natural ecosystems have adapted to climate. Australiaís present climate is one of extremely variability: fire, flood and drought. Our flora and fauna has adapted to survive this great variability.

If as a result of increased greenhouse gas emissions, the climate changes, our whole world will be affected, but at this stage it's impossible to predict by exactly how much. If rainfall increases, our dams and drains may no longer be able to cope. If some farm lands experience 'bad' seasons more frequently, many farmers may go broke. On the other hand, there may be new opportunities to grow different crops. If the climate variability changes, our native animals and plants may not be able to adapt in time, and biodiversity would be threatened.

An increase in temperature of a few degrees may not sound all that great, but itís likely to have a profound effect on your community. From the manner in which it receives and treats its food and water, right through to the total environment on which weíre so dependant. Together with the temperature increase, scientists are also predicting that the sea level will rise (mainly through thermal expansion of water). The best estimate is a rise by between 10 and 30 cm by 2030 (as compared with 1990 levels), in line with a doubling of CO2. Again, this may not sound much, but if you add it on top of a storm surge - in particular, storm surges associated with tropical cyclones - (and more storms is one possible outcome of climate change), and the extra height represents a significant increase in risk to low lying coastal areas and tropical islands.

But, this is just one possibility based on one scenario. Even though this is the scenario that is considered most likely, there are several other scenarios in which the levels of greenhouse gases are higher or lower. Also, even if you could accurately predict the level of greenhouse gases in future decades, you still wouldn't be able to predict the exact changes that would occur to our climate. There are many factors which just aren't know well enough. One of these is feedback mechanisms.

Feedbacks

Feedbacks are processes which act to modify the response of a system to a change forced upon it. Some feedbacks increase the global warming (positive feedbacks), while others act to reduce it (negative feedbacks).

For example, warmer temperatures will lead to increased evaporation, and thus more water vapour in the atmosphere. As water vapour is a major 'greenhouse' gas, this will add to the warming (positive feedback). However, more water vapour in the air is likely to allow more clouds to form. Clouds will have their own influence on world climate. Depending on their type and altitude, the overall effect of more clouds would be twofold: they'd reflect back solar radiation into space and reduce warming (negative feedback); and they'd reflect back more heat to Earth, thereby increasing warming (positive feedback). Which effect will dominate is not clear at present.

As the planet warms, ice and snow in some regions will melt to reveal a darker underlying surface (be it ocean or land). The darker surface will absorb more heat, thus increasing the warming process (positive feedback).

These are just two examples of feedbacks present in the climate system. There are many more. Unfortunately, our quantitative understanding of some of these feedback mechanisms is still sketchy, and the way in which these mechanisms are incorporated into current climate models is the subject of basic research. Scientists do know that feedback-induced changes have the potential to significantly enhance or reduce predictions of 'greenhouse' warming.

Preparing for change

Observations during the past century have enabled scientists to determine that global average temperature has already increased by 0.3 - 0.6oC - a warming broadly consistent with the prediction based on climate models, but of the same order of magnitude as natural temperature flucuations.

Although the increased temperature could be attributed to natural variation - a small blip on a million-year temperature chart that is full of ups and downs - the possibility that it's due to the enhanced greenhouse effect cannot be ruled out. This presents nations, communities and individuals with a knotty problem: how to respond when we don't know with any certainty whether the changes are happening already, what the changes will be, and how quickly they will occur?

One approach is simply to do nothing until we know definitely what is happening. But this may mean that in twenty or thirty years time we are suddenly faced with very large climatic changes to which we have to respond rapidly, with considerable social and economic cost. Reducing the production and release of greenhouse gases now so that we slow the rate of change seems to be a more logical response. It would give us more time for research and to prepare for change.

What can you do?

If an increase in greenhouse gas emissions leads to an enhanced greenhouse effect, its impact will be global. It's being caused by the way we, particularly in the developed world, live our lives. Greenhouse gases are generated by many of the processes that drive our Western society - by the way we generate and use energy, the manner in which we grow our plants and animals, the way in which we dispose of our waste.

It's only in recent decades that we've started to understand what the consequences of our lifestyle might be. There are alternatives to the way we currently run our lives; alternatives that reduce the amount of greenhouse gases that are produced. Many people believe it is important that we adopt these alternative approaches. Many approaches simply involve cutting down on wastage, and increasing efficiency in matters of energy generation and consumption. Such changes make good sense, regardless of any possible threat by an enhanced greenhouse effect.

To make changes that are meaningful, the Australian community as a whole needs to make wiser decisions on how it uses its resources so that we minimise greenhouse emissions. As an individual, if you really want to make a difference, you should be active in this decision- making process. For example, one of the best ways for a community to cut back on its greenhouse emissions is to cut back on its energy consumption. Using effective insulation at home, wise use of heating, minimising the use of the private car, encouraging good public transport (and using it) are all ways of cutting down on greenhouse emissions. Everyone who is concerned, and this should be all of us, should be active in the public debate.

It's also important that you keep up-to-date about current 'greenhouse' research activities and results. You'll be in a better position to enter the debate about how we ought to react as a community.

The climate system

The Earth's climate system is driven by energy from the sun, and the rotation of the Earth. Heat builds up in equatorial regions because they receive more solar radiation than higher latitudes. Atmospheric and oceanic circulation systems redistribute this heat towards the Poles. (In this way, the elements of the climate system are tied together through the exchange and redistribution of energy in its various forms.)

In order to maintain a stable temperature at the Earth's surface, a balance must be reached between incoming and outgoing radiation. (Otherwise, the Earth's surface would continue to get warmer or cooler.)

The climate system remains in a steady state unless forced to change. If one part of the system changes, the rest of the system adjusts to that change. Since all element of the system are linked, a seemingly small change in one part of the system can have implications for the entire system.

Modelling the climate system

Most global climate models divide the Earth's surface into a number of grid squares bounded by lines similar to latitude and longitude. And, vertically, they divide the planet into a number of layers representing levels in the atmosphere. In this way, the earth-atmosphere is divided into a number of boxes.

Mathematical equations, based on the laws of physics, imitate the state of the atmosphere in each box. A picture of the behaviour of the atmosphere is built up through time as high power computers solve the mathematical equations in small time steps. Eventually this leads to a representation of Earth's climate.

In the most advanced models, the oceans are divided up in the same way - split up into grid boxes. The ocean system is linked with the atmosphere system to give the best representation of how our climate works.

Once scientists have produced a reasonable representation of the present climate, they input the projected levels of greenhouse gases, repeat the calculation and compare the result with the original. Again, more advanced techniques and greater computing power enables more realistic models in which gas concentrations are steadily increased with time. The climate system reacts to these changes.

Climate change in Australia's region

What can Australians expect in the future? Scientist don't know for certain- there are just too many unknown factors, and at this stage there are no detailed and accurate predictions available. However, there is enough information to make qualified statements of a plausible future- climate change scenarios. These scenarios are being refined and updated all the time.

At the time at which this article was written, the most up-to-date climate change scenarios were developed by the Climate Impact Group at CSIRO's Division of Atmospheric Research in November of 1992. Based on a range of business-as-usual emission scenario, they estimate that by 2030, Australia will probably be warmer (based on emissions at the upper end of the range). Coastal regions north of the latitude 25oS may experience an increase of up to 1.5oC. South of that latitude the increase may be up to 2.0oC. Inland (more than 200km from the coast), it may get warmer by 2.5oC. At the lower end of the range of emission scenarios, climate change may still not be detectable.

By 2030, regions that experience summer rainfall may experience up to 20% more rain. Some areas that experience winter rainfall may receive less rain (by up to 10%), others more rain (by up to 10%). Itís also possible that, by 2030, Australia will experience more extreme weather events. More very hot days, more floods and more dry spells and even fewer frosts, and less snow.

These are not predictions but examples of the kinds of changes that could occur, based on what we know at the moment. For a copy of the complete climate change scenario for the Australian region, write to the Climate Impact Group, CSIRO Division of Atmospheric Research, Private Bag 1, Mordialloc Victoria 3195.

The main greenhouse gases include: water vapour, carbon dioxide, methane, nitrous oxide, ozone and the chlorofluorocarbons. Through complex chemical interactions in the atmosphere, other gases, notably carbon monoxide (CO), also play an indirect role in the greenhouse effect by influencing the levels of other greenhouse gases.

Water vapour (H2O) is the most important greenhouse gas. It's responsible for about 75% of the natural greenhouse effect. As Earth warms due to the increases in the other greenhouse gases, the amount of water vapour in the atmosphere is also likely to rise. Unlike most of the other greenhouse gases, the amount of water vapour directly put into the atmosphere as a result of human activities is negligible compared with atmospheric water vapour present naturally. Consequently, while it's a very important greenhouse gas, you don't hear it being discussed as much as the other greenhouse gases. It enters the atmosphere mainly through evaporation from the oceans. Carbon dioxide (CO2) is probably the most significant gas for us to consider as it is making a major contribution to the enhanced greenhouse effect, and human activity has largely been responsible for its increase. A substantial part of the observed increase in atmospheric carbon dioxide can be attributed to the burning of fossil fuels such as oil, coal and gas. Less well known is the amount of CO2 released from the burning of plant material as a result of deforestation. However, increases in the levels of atmospheric CO2 are well documented. From an analysis of the air trapped in ice sheets, scientists have shown that the concentration of carbon dioxide during the last glacial age was only about 190 parts per million by volume (ppmv), compared with the pre-industrial level of about 280 ppmv and the current concentration of about 350 ppmv.

Methane (CH4) is released to the atmosphere from a number of sources: gas drilling, venting and transmission; coal mining; landfills and animal wastes; oceans and fresh waters; natural marshes and swamps; rice paddies; the burning of vegetation; and through digestive processes of ruminant animals and termites. The most recent estimates suggest that between 40 and 70% of the methane released globally is due to human activity. Pre-industrial levels of methane have risen from 0.8 ppmv to 1.72 ppmv. Although the concentration of methane is much lower than CO2, methane is estimated to be 10 to 20 times more effective per molecule at absorbing infrared radiation than CO2. The good news is that the rate of increase of methane in the atmosphere seems to be slowing down (the bad news is that no-one knows why).

The greenhouse gases

Nitrous oxide (N2O) is released by processes in the soil, both agricultural and natural; the burning of vegetation and fossil fuels; and by life in the oceans. Pre-industrial levels of 288 parts per billion by volume have risen to 310 parts per billion by volume.

Ozone (O3) can be found in varying concentrations at all levels of the atmosphere. The maximum concentration is in the middle and lower stratosphere (15-35 km) in a region known as the ozone layer where it shields the planet from damaging ultra-violet radiation. Because ozone reacts readily with other gases in the air, it remains in the lower atmosphere (troposphere) for a relatively short time.

Chlorofluorocarbons (CFCs), are not present in great concentrations but they are still a significant greenhouse gas because some types of CFCs persist in the atmosphere (particularly in the stratosphere) for decades (even centuries). They absorb large quantities of heat. They are also a human-created gas that didn't exist before this century. They're used as refrigerants and blowing agents for foam. The use of CFCs is now being phased out in many countries. Oddly enough, because CFCs destroy ozone, another greenhouse gas, their greenhouse warming effect is effectively cancelled out.