Global warming describes the overall trend of rising world temperatures over time. Most scientists agree that the recent gradual increase in temperatures has been caused by human activities, especially the burning of fossil fuels for energy.

The main impact of global warming is climate change. Evidence of climate change includes an increase in average global temperatures; ice melting in polar and mountain regions; rising sea levels; and an increase in extreme weather events. Action must be taken now to reduce greenhouse gas emissions and the future impact of global warming on the climate.

Geographical knowledge and understanding
- Develop knowledge and understanding of global warming and climate change.
- Investigate the interaction between people and the atmosphere and the response of the atmosphere and its effect on people.
- Investigate and develop policies to manage climate change.

Geospatial skills
- Interpret maps, photographs and graphs in relation to climate change.
- Compare maps to find the spatial association between carbon dioxide production and Gross Domestic Product.

Crowds watch as the 70-metre front wall of the Perito Moreno Glacier in Argentina breaks down in March 2004. The glacier is breaking up because it has been weakened by global warming.
carbon credit: a measurable action, such as planting trees, that helps reduce the atmospheric concentration of CO$_2$. One carbon credit is equal to one tonne of CO$_2$. Carbon credits can be traded.
carbon sinks: places or processes that remove greenhouse gases from the atmosphere
choropleth maps: these maps use light and dark shades of the same colour to show a pattern. The darker shades show 'most' of a feature and the lighter shades show the 'least'.
climatic: the long-term variation in the atmosphere, mainly relating to temperature and precipitation
climatic change: any change in climate over time, whether due to natural processes or human activities
CSIRO: Australia's Commonwealth Scientific and Industrial Research Organisation
dengue fever: primarily a disease of tropical and subtropical areas, spread by a species of mosquito
emissions: substances such as gases or particles discharged into the atmosphere
enhanced greenhouse effect: increased ability of the Earth's atmosphere to trap heat, warming the Earth and the atmosphere
fossil fuels: fuels, such as coal, oil and natural gas, that come from the breakdown of organic matter. They have formed in the ground over millions of years.
global warming: describes the observable trend of rising world temperatures over the past century, particularly during the last couple of decades
greenhouse effect: the result of the sun's heat being trapped within the atmosphere rather than reflected out into space. This causes a significant increase in temperature.
islet: a small island
per capita: a measurement presented in terms of units per person
permafrost: ground that has remained below 0 °C for at least two consecutive years
photosynthesis: process in plants of using the energy from sunlight to convert water and carbon dioxide into carbohydrates and oxygen
precipitation: water falling from the atmosphere to the Earth as rain, snow, hail, sleet or dew
ratify: to make an agreement official and binding
respiration: process used by organisms to obtain energy by using oxygen and releasing carbon dioxide
spatial association: the relationship between two or more features in a selected region
spatial change over time: the degree to which an area has changed its geographic characteristics, features or patterns of use over a period of time
spatial concepts: key geographic ideas used by geographers to describe the world around them
spatial interaction: the strengths of the relationships between phenomena and places in the environment, and the degree to which they influence or interact with each other
thermal expansion: when water is warmed, it expands and therefore takes up more space
tundra: a treeless plain that is characteristic of the arctic and subarctic region
Global warming describes the observable trend of rising world temperatures over the past century, particularly during the last couple of decades. The average global surface temperature has warmed by about 0.74 °C in the past 100 years. Most scientists agree that this increase in temperature is due to human activities, especially the burning of fossil fuels.

Global warming is causing climate change. Climate change means any change in climate, whether due to natural processes or human activities. Evidence of the current change in our climate includes an increase in average global temperatures, ice melting in polar and mountain regions, rising sea levels and more extreme weather events.

Climate change is not new — it has been happening for millions of years. Ice ages come and go, and sea levels rise and fall. During colder periods, glaciers increase, icesheets and the polar icecaps expand and sea levels fall. During warmer periods, glaciers, icesheets and icecaps retreat, and sea levels rise.

However, the current rapid rate of warming and its impact on climate may damage many species and ecosystems. The Earth's animals and plants are used to slow changes, which allow time for species to adjust to climatic changes such as rising temperatures.

The greenhouse effect is a natural process. The gases in the Earth's atmosphere act like the glass of a greenhouse, trapping the sun's warmth. Without the atmosphere, the Earth's surface would be about 15 °C cooler than it is.

The enhanced greenhouse effect

1. Heat from the sun
2. Heat trapped by greenhouse gases
3. Heat radiating back into space
4. Greenhouse gases produced by power stations and industry burning fossil fuels
5. Carbon monoxide emitted from vehicle exhausts
6. Chlorofluorocarbons (CFCs) escaping from old dumped refrigerators
7. Nitrous oxide released from fertilisers
8. Methane from waste dumps and from animals
9. Water vapour from cooling towers
10. Carbon dioxide released by logging forests
Water vapour and gases such as carbon dioxide and methane are responsible for the greenhouse effect. These gases make up only a small proportion of the atmosphere, but any variation in their amounts can have an effect on the Earth’s temperature.

The enhanced greenhouse effect is the increased ability of the Earth’s atmosphere to trap heat. Since the Industrial Revolution, the composition of the Earth’s atmosphere has changed. Humans have added extra carbon dioxide (CO$_2$) and other greenhouse gases to the air, particularly by burning fossil fuels (oil, coal and gas) and by cutting down trees. With more gases in the air to trap heat, the Earth’s temperature is rising.

### THE GLOBAL CARBON CYCLE

The carbon cycle explains how carbon dioxide is added to and removed from the atmosphere. Carbon dioxide is exchanged by photosynthesis and respiration. Oceans act as carbon sinks, absorbing carbon dioxide and eventually transporting and storing it deep in the ocean floor. Over enormous periods of time, carbon can also be converted to other carbon resources such as oil, coal, gas and coral reefs.

An imbalance has occurred in the carbon cycle because more carbon is being released than is being absorbed or stored away. This has occurred very rapidly since the Industrial Revolution — before the 1800s, the concentration of CO$_2$ in the atmosphere was about 280 ppm (parts per million); it was 380 ppm in 2005, an increase of about 30 per cent in just over 200 years.

### Activities

**Understand**

1. Outline the difference between global warming and climate change.
2. Use the analogy of a car in the sun with its windows up to explain the greenhouse effect.
3. Explain the difference between the greenhouse effect and the enhanced greenhouse effect.
4. Name two important carbon sinks.
5. Explain why an imbalance in the carbon cycle has occurred in recent times.

**Think**

6. Study the diagram of the enhanced greenhouse effect. List five human activities that add greenhouse gases to the environment.
7. Study the diagram of the global carbon cycle.
   (a) List the locations with the three highest concentrations of carbon.
   (b) How can trees both contribute to, and reduce, the amount of atmospheric carbon?
8. In relation to current climate change, why can’t the conversion of carbon to oil, gas and coal be regarded as a useful sink?
9. What factors could affect the ability of the Earth’s ecosystems to adapt to global warming and climate change?

### Worksheets

6.1 Climate change crossword
6.2

ARE THERE PATTERNS RELATED TO CLIMATE CHANGE?

PATTERNS OF WARMING

Observations of global warming and climate change have been noted for many years, but are now forming more obvious patterns.

Records of temperatures around the world, kept since the 1860s, show an upward trend in global average air and ocean temperatures. During the last century, the Earth’s average temperature increased by 0.74°C. In the last 50 years, there were more hot days and nights, and fewer cold days and nights. Nine of the ten warmest years since 1860 occurred between 1996 and 2006.

Average global temperature, 1880–2004

Sea levels rose at an average rate of 1.8 mm per year over the last thirty years. A rise in sea level is due to the warming and consequent expansion of sea water plus the inflow of water from melting icecaps, icesheets and glaciers. Warmer temperatures have caused widespread melting of snow and ice and the retreat of glaciers, icesheets and icecaps.

In some regions, precipitation patterns have altered. Parts of southern Asia, southern Africa and southern Australia are getting drier. Northern Europe, northern and central Asia and eastern parts of North and South America are getting wetter.

Extreme weather events such as heatwaves, droughts, floods and tropical cyclones are becoming more frequent and more intense. Other changes to normal patterns have been observed in some regions: the early arrival of spring and the late arrival of autumn; changes in plant growth and animal behaviour; and the spread of disease.

PATTERNS IN AUSTRALIA

Australia’s Bureau of Meteorology has calculated that Australia has warmed by 1°C since records began in 1861. Observations of global warming and changing climate patterns in Australia include:

- an increase in the number of very hot days
- an increase in night-time temperatures
- a decrease in the number of very cold days
- a decrease in the occurrence of frost
- an increase in intense cyclones and severe low-pressure systems in the south-east
- an increase in the rate of flooding and of drought over the past 20 years.

WHAT CAUSES WARMING?

Some scientists argue that the climate change we are experiencing is due to natural cycles that occur over millions of years. These cycles correspond with cold (ice ages) and warm (interglacial) periods. As a global average, ice ages have been about 10°C cooler than we experience now, while the interglacial periods have been about the same temperature as today.

However, the rate of warming now is far greater than ever before. Most scientists agree that the current increase in global temperatures is mostly due to human activity rather than natural causes. Data show that the concentration of carbon dioxide in the atmosphere has increased rapidly since the Industrial Revolution. This corresponds with an increase in burning fossil fuels for energy. Analysis of air bubbles trapped in Antarctic ice shows that the concentration of CO₂ is the highest it has been for at least 650,000 years. There is now more CO₂ in the atmosphere than humans have ever experienced before.

Using computer modelling, most scientists have also concluded that the rapid warming cannot be solely explained by natural causes such as increased solar or volcanic activity.
Scientists use computer models to make projections about future patterns of warming. The models used are based on factors such as CO₂ and other greenhouse gas emissions, degrees of economic growth and population increase, and actions taken to reduce greenhouse gas emissions.

In 1988, the Intergovernmental Panel on Climate Change (IPCC) was established by two United Nations organisations: the World Meteorological Organization and the United Nations Environment Programme. The purpose of the IPCC is to study climate change. Its role is to:

- examine current scientific knowledge about climate change
- assess the world’s vulnerability to climate change and how to adapt to it
- assess options for limiting greenhouse gas emissions and other ways to mitigate climate change.

The IPCC released its fourth report in 2007. Its estimates of projected future climate change include:

- A warming of about 0.2°C per decade will occur for the next two decades. Even if the concentration of greenhouse gases is kept constant at year 2000 levels, a further warming of about 0.1°C would be expected.
- By 2099, the global temperatures are likely to increase to between 1.1°C and 6.4°C, depending on the rate of greenhouse gas emissions.
- By 2099, the global average rise in sea level is likely to increase to between 0.18 and 0.59 metres. These estimates do not include potential melting of the Greenland and Antarctic icesheets because there is still insufficient research and data about this.
- Over the next century, snow cover is projected to contract, depth of permafrost is projected to decrease, sea ice is projected to shrink and heatwaves will continue to become more frequent.
- Over the next century, heavy precipitation events will continue to become more frequent. Increases in the amount of precipitation are very likely in high latitudes while decreases are likely in most subtropical land areas. Due to increases in tropical sea surface temperatures, it is likely that tropical cyclones will become more intense.
- Carbon dioxide emissions already in the atmosphere will continue to contribute to warming and rising sea levels for centuries because this gas lasts in the atmosphere for a very long time.
Comparing maps to find spatial associations
Geographers use spatial concepts to describe the world around them. One of these is spatial association, which shows the relationship between two or more features in a selected region. Patterns can be observed by comparing choropleth maps.
A strong positive association means that there is an obvious pattern, e.g. high CO₂ production and high energy use, or low CO₂ production and low energy use. A strong negative association would be a general pattern that shows high CO₂ production and low energy use, or vice versa. A medium association would show a pattern, but with some variation. A weak spatial association would show little or no pattern.

Study these maps to find any relationships.
1. Name three countries that have high energy use and high CO₂ emissions.
2. Name three countries that have low energy use and low CO₂ emissions.
3. List two countries that have high energy use and low or medium CO₂ emissions.
4. Are there any countries that have low energy use and high CO₂ emissions?
5. Write a summary statement describing the degree of spatial association between CO₂ emissions and energy use.
6. As a class, brainstorm some possible reasons to explain this pattern.
GREENHOUSE PRODUCERS

It is important to be careful about how data are read and interpreted. When looking at the total production of CO$_2$, Australia produces only around 1.4 per cent of the world total of energy-related CO$_2$ emissions. This compares favourably with the USA and China.

However, when CO$_2$ production is measured on a **per capita** basis, it shows how much is produced for every person in the country. This figure allows emissions to be compared directly to population size. Australia has high per capita emissions and produces much more CO$_2$ than France and Indonesia, which have higher populations.

![CO$_2$ emissions from fossil fuels, 2004](image)

Source: Data derived from International Energy Agency

**CO$_2$ emissions for selected countries, 1994–2004**

Source: Data derived from International Energy Agency

Australia’s CO$_2$ production is so high because about half our fuel consumption relies on burning brown coal, a major CO$_2$ producer. Other major sources are land clearing, mining and agriculture (mainly methane produced by cattle and sheep).

**Activities**

**Understand**

1. Briefly describe the change in global temperature between 1880 and 2004.
2. List observations that reflect patterns of global warming and climate change.
3. What evidence is there that climate change is occurring in Australia?
4. What do most scientists think is causing global warming?
5. Describe the change in CO$_2$ and temperature over the last 650 000 years.
6. Refer to the map of carbon dioxide emissions per person. Describe the global pattern of per capita carbon dioxide production.

**Think**

7. Compare the graphs showing total and per capita carbon dioxide emissions.
   (a) How are the data different?
   (b) Why must you be careful when reading and interpreting these types of data?
   (c) Which data might the following prefer to use? Justify your answer.
      • Coal industry
      • Environmental support groups

8. Predict what will happen to CO$_2$ production in Australia if emissions continue at their present rate and the population increases.
9. Outline why Australia is one of the highest per capita producers of carbon dioxide in the world.

**Communicate**

10. What is the IPCC? Describe the role of the IPCC.
12. Describe the **spatial interaction** between people and climate change. Describe how human activity has affected the climate and how climate change, in turn, is affecting people.
13. Conduct a debate on the following: Is it fair to ask poor countries that produce low per capita emissions to reduce emissions further, while rich countries that produce high per capita emissions do not cut their emissions?

**Worksheets**

6.2 Scanning images
According to the IPCC 2007 report, global surface temperatures are likely to increase by between 1.1 °C and 6.4 °C over the next 100 years, depending on the rate of greenhouse gas emissions. This will have a huge impact on the Earth’s coldest regions, where the effects of climate change are already being felt.

**MELTING GLACIERS**

Glaciers in both the northern and southern hemispheres have been shrinking for over a century — some in low-lying areas have almost disappeared. Glaciers are melting and they will continue to shrink as the Earth’s temperature continues to rise.

- **Kenya:** 92 per cent of the Lewis Glacier — Mt Kenya’s largest — has melted in the past 100 years.
- **Tien Shen Mountains, China:** glacial ice decreased by 25 per cent in the past 40 years.
- **Kyrgyzstan:** during 1959–88, 1081 glaciers in the Pamir–Altai disappeared.
- **Garhwal Himalayas, India:** glacial retreat is occurring at a record pace. Scientists predict all central and eastern Himalayan glaciers will be gone by 2035.
- **India:** glaciers in the Himalayas are retreating at an average rate of 15 metres per year, consistent with the rapid warming recorded at Himalayan climate stations since the 1970s.
- **Mt Everest:** the Khumbu Glacier has retreated over 5 kilometres since 1953. It is a popular climbing route to the mountain’s summit.
- **Bhutan:** as Himalayan glaciers melt, glacial lakes are filling and are in danger of flooding. Average glacial retreat in Bhutan is 30–40 metres per year.
- **Austria:** the discovery of a frozen Stone Age mummy in a melting glacier, in the Oetztal Alps, shows that glacial ice has now decreased more than at any time during the past 5000 years.
Spain: half of the glaciers that existed in 1980 are gone.
Glacier National Park, Montana, USA: if glacial retreat continues at its current rate, all glaciers in the park will disappear by 2070.
Canadian Rockies: the Athabasca Glacier has retreated 0.5 kilometres in the last 60 years. In British Columbia, the Wedgemont Glacier has retreated hundreds of metres since 1979, as the climate has warmed at twice the global average.
Alaska, USA: between the mid-1950s and mid-1990s, 67 glaciers have thinned by an average of 0.5 metres per year. This increased to nearly 1.8 metres per year from the mid-1990s to 2000–2001.
Venezuela: only two of six glaciers in the Venezuelan Andes remain from 1972. Scientists predict these will be gone in the next 10 years.

Andes Mountains, Peru: the edge of the Qori Kalis glacier retreated by 4.0 metres each year between 1963 and 1978. By 2002, the rate increased to 30.1 metres per year.
Argentina: glaciers in Patagonia have receded by an average of almost 1.5 kilometres over the last 13 years.
Heard Island, Australia: air temperature rose 0.7 °C between 1947 and 2001. Since 1947, the island’s 34 glaciers have decreased by 11 per cent in area and 12 per cent in volume.

The amount of melt water available for human consumption, agriculture and hydroelectricity will continue to decline as glaciers retreat and snow cover decreases. Many settlements in mountain regions rely on water stored in glaciers and in snow cover for all or part of their water supply. Glaciers also feed river systems with melt water so the amount of water available in these rivers for settlements downstream will also decline.

The Arctic

Scientists are observing dramatic changes in the Earth’s polar regions. During the past 100 years, average Arctic temperatures increased at almost twice the average global rate. During the last 30 years, satellite data have shown that the average annual extent of Arctic sea ice has shrunk by 2.7 per cent per decade. Compared with 20 to 40 years ago, ice thickness has decreased by an average of 1.2 metres — about a 40 per cent decrease in the volume of ice. The Arctic icecap has lost an area the size of Tasmania since 1970.

Temperature measurements using ice cores and tree rings show that the twentieth century was the warmest century in the Arctic since 1600. The permafrost in the region is thawing and causing the ground to subside in many areas. Due to this thawing, buildings in Russia and Canada have collapsed. Oil pipelines, roads and airports have also been affected.

‘Drunken’ forests in Alaska. The trees are leaning and falling over because the permafrost is melting.
In Siberia, large areas of **tundra** permafrost are melting. In some regions, thawing of the upper ground is occurring at a rate of nearly 20 centimetres per year.

Some possible benefits of the thawing include more productive fisheries, easier access to shipping routes across the Arctic, and easier mining of gas and oil deposits in the region.

**ANTARCTICA**

Surface temperatures have remained fairly stable over most of Antarctica during the last 50 years, and there has been little change in the overall extent of Antarctic sea ice. However, the Antarctic Peninsula has experienced a warming of about 2.5 °C. Many glaciers have retreated in this region and several ice shelves have broken up in recent years.

In early January 2005, a giant 11,655 square-kilometre iceberg named B-15A broke off from the Ross Ice Shelf near Cape Adare in Antarctica. Later, in October, the iceberg broke into a number of giant pieces after it was affected by waves generated six days earlier by a storm located 13,500 kilometres away in the Gulf of Alaska. Scientists are worried an increase in severe storms due to climate change will increase these events and lead to a more rapid rise in sea levels.

This event follows a previous one in Antarctica between 1995 and 2002, when the Larsen A and B ice shelves collapsed and disintegrated.
Activities

Understand
1. Why might cold regions show more obvious signs of warming compared to warmer regions?
2. Describe the change in average Arctic temperatures during the last 100 years.

Think
3. Describe the changes shown in the glacier photographs. Work with another person and brainstorm possible consequences of continued glacial melting. Present your ideas in a futures wheel like the one below right.
4. Describe the impact of thawing and melting in the Arctic. Identify any advantages and disadvantages that could result.
5. Describe the impact of climate change in cold environments in terms of spatial change over time.

Use ICT
6. Visit the website for this book and click on the Disappearing Glaciers weblink for this chapter (see ‘Weblinks’, page vii) to see more photographic evidence of disappearing glaciers.
7. Use the internet to investigate how global warming is affecting polar bears. Present a summary of your findings

Design and create
8. Use the information on these pages and an atlas to map the observed changes over time to glaciers and other ice areas. To download a blank map of the world, visit the website for this book and click on the Blank World Map weblink for this chapter (see ‘Weblinks’, page vii). You will also need coloured pencils. Design symbols, annotate (make notes) and follow correct map conventions (BOLTSS). Describe the pattern shown on your map.
9. Imagine it is 2050 and that you are a journalist preparing a documentary about continued global warming and glacial melting. Design your half-hour documentary using a number of locations around the world. Draw up a plan detailing the places visited, the footage filmed (and why you have chosen it), and the commentary to accompany the footage. You might like to break this down into five-minute segments. You could develop this as a multi-media presentation or display your plan on the classroom wall.
6.4

WARM OCEANS AND RISING SEA LEVELS

Over the past 35 to 45 years, the world’s oceans have warmed by an average of 0.06°C between the surface and a depth of around 3000 metres. Most warming occurred in the top 300 metres, where the average warming was 0.31°C.

The result was a rise in global sea levels of between 10 and 20 centimetres over the last 100 years. This was caused by more water entering the sea from melting glaciers and sea ice, and by thermal expansion (water expands as it heats, increasing in volume and taking up more space).

DISAPPEARING ISLANDS

There is already evidence that sea levels are rising. Monitoring across the Pacific shows a dramatic rise in sea level from Papua New Guinea, south-east to Fiji. Data from 16 sites show that Fiji’s average shoreline has retreated by about 15 centimetres per year over the past 90 years. In Western Samoa, the coastline has receded by about 46 centimetres per year over the past 90 years.

Many low-lying atoll countries — Kiribati, Maldives, Marshall Islands, Tokelau, Tuvalu, Solomon Islands and Vanuatu — are under threat from rising sea levels. Two tiny uninhabited islets in Kiribati, Tebua Tarawa and Abanuea, disappeared beneath the waves in 1999 due to rising sea levels.

The Maldives

The 2004 Boxing Day tsunami exposed how vulnerable the Maldives is, when waves swept across many low-lying islands, causing widespread destruction of fruit plantations. The relatively low number of deaths was due to the fact that most of the population live in Male, which is protected by a huge sea wall. It is understandable that the Maldives was one of the first countries to sign the Kyoto Protocol, which seeks international agreement to cut back carbon dioxide emissions.

The Maldives consists of 1196 tiny islands, most of which are only around 2 metres above sea level. The Maldives is home to around 300,000 people.

Tegua, Vanuatu

Sixty-four people once lived on Tegua Island, in northern Vanuatu. The sea has been advancing on this small island for many years; killing coastal coconut trees and contaminating the drinking water in wells with salt water. As a result, Tegua was the first settlement to be relocated to higher ground due to rising sea levels. Funding from the Canadian Government, Pacific Regional Environment Program and United Nations built a new village 0.5 kilometres inland and provided water tanks to store drinking water for the six-month dry season.

Low-lying islands in the Pacific are under threat of disappearing due to rising sea levels.
Small island states produce very small amounts of greenhouse gases, yet they are the ones experiencing the first impacts of rising sea levels. Many of these states are very poor and will need financial assistance.

### LOW-LYING REGIONS

In some locations, a 1 mm rise in sea level can cause a 1.5 metre loss of coastline. Under severe threat are low-lying coastal areas, such as Southern Florida in the United States; Asian countries, such as Bangladesh; and low-lying nations, such as the Netherlands.

### FUTURE PROJECTIONS

Scientists using computer models think sea levels could rise by half a metre over the next century. The rise in sea levels occurring now was caused by warming that happened decades ago. The global warming that will continue to occur will most likely cause sea levels to rise even higher. Many climate refugees could be created by rising sea levels.

Sea levels are likely to continue to rise long after CO\textsubscript{2} emissions and global temperatures stabilise.

![Graph showing time taken to reach equilibrium for different factors affecting sea level rise](graph.png)

**Activities**

**Think**

1. Describe the main causes of rising sea levels.
2. Why are many islands in the Pacific under threat from rising sea levels?

3. Outline what you think is meant by the term *climate refugee*.
4. According to climate scientists, what is the most probable future rise in sea level?
5. Study the graph and answer the following:
   (a) When are CO\textsubscript{2} emissions expected to peak? How long after this time is CO\textsubscript{2} expected to stabilise?
   (b) When is global temperature expected to stabilise?
   (c) Describe what is expected to happen to the rise in sea levels, over time, as a result of ice melting and thermal expansion.

6. Study atlas maps showing population density and environments. Record the population densities of the locations threatened by rises in sea levels. Write a summary paragraph describing the consequences of rising sea levels for people and environments.

**Teamwork**

7. Work with three other students. Imagine you are on a committee that is developing a policy to help people from low-lying countries deal with rising sea levels. Develop three strategies that will assist them. Should special attention be given to low-polluting countries? Give an example.

**Use ICT**

8. Visit the website for this book and click on the Sea Level Changes weblink for this chapter (see ‘Weblinks’, page vii). Select some images and animations about the predicted impact of different changes in sea level. Choose one region to study in detail, and produce a series of maps and descriptions to show what might happen.

---

Tegua Island, a low-lying island in Vanuatu on which settlements have been relocated due to rising sea levels.
As the atmosphere and oceans warm, more thermal energy becomes available to affect the weather. Data collected over a number of years show an increase in the number of extreme weather events around the globe. For example, the hottest European summer on record occurred in 2003, and the first and only hurricane ever recorded in the South Atlantic — Hurricane Catarina — occurred in Brazil in March 2004.

The economic losses from these events are increasing. People in developing countries are likely to be affected much more than those in developed countries.

**INCREASED RAINFALL**

Warm air holds more water vapour. Therefore, there is potential for more, and heavier, rainfall to occur in some locations. Heavy rainfall events have increased over time and climate models show that future precipitation will often occur in larger downpours and heavy snowstorms.

In the 1960s, seven million people were affected by flooding annually; in 2005, 150 million were affected. As more of these events occur, there will be a rise in flood and storm damage, and corresponding loss of life and property. Soil erosion, and river and ocean pollution, will also increase.

![Global economic losses as a result of extreme weather](chart)

**Distribution of selected extreme flooding events**

- **2000 South-eastern Norway**
  - The wettest year since records began in 1895

- **2002 China**
  - One hundred million people were affected by floods.

- **2002 North Korea**
  - Huge floods occurred when 40 per cent of North Korea’s annual rainfall fell in one week.

- **1999 Mount Baker, Washington**
  - World record for the most snowfall in a single winter season, when 2895 cm of snow fell between November 1998 and the end of June 1999.

- **1998 Texas**
  - Record downpours and severe flooding in south-east Texas caused $1 billion in damage and 31 deaths.

- **2001 Pampas region, Argentina/Uruguay**
  - Nearly 3.2 million hectares of land in the Pampas region were flooded after three months of high rainfall. Mean annual precipitation in this region has increased by 35 per cent in the last half of the twentieth century.

- **2000 Buenos Aires, Argentina**
  - Heaviest rains in 100 years, with more than four times the average monthly rainfall falling in five days.

- **1999 Venezuela**
  - The heaviest rainfall in 100 years (1.2 m in December) caused massive landslides and flooding that killed approx. 30,000 people. Population growth in vulnerable areas and forest clearing contributed to the high death toll.

- **2007 England**
  - The wettest July on record, with more than three times the average monthly rainfall falling in five days.

- **2007 Bangladesh, northern India and Nepal**
  - Twenty-five million people were displaced, and thousands died, many from diseases such as malaria and encephalitis.
Flash floods and mudslides cut a swathe through Caraballeda, Venezuela, in December 1999.

HEATWAVES AND DROUGHTS

Some regions will experience increased heat and drought rather than more rain. The percentage of the Earth affected by serious drought more than doubled between the 1970s to the early 2000s. More frequent, severe heatwaves are occurring, causing illnesses and deaths in some cases.

Droughts cause losses in crops, livestock, fisheries and wildlife, and decrease river flows and water quality. Some locations that have experienced extreme drought and fire events include:

- Europe — the hottest summer on record in 2003, when 23,000 people died in June and July as temperatures were greater than 40°C
- Kenya — the worst drought on record in 2001
- Spain, Portugal and France — forest fires due to drought in 2005
- South Africa — one of the driest Decembers on record, fuelling extensive fires in Western Cape Province in January 2000
- Southern India — a heatwave in May 2002 resulted in the highest one-week death toll on record.
- Tajikistan — the lowest rainfall in 75 years occurred in 2001.
- Mexico — the worst fire season ever in 1998 during a severe drought
- Mediterranean, including Greece and Italy — intense drought and fires in 1998
- Texas — a heatwave in the summer of 1998 claimed more than 100 lives.
- Florida, Texas and Louisiana, USA — the driest period in 104 years from April to June in 1998; the worst wildfires in Florida in 50 years.

A wildfire burns close to homes in north-western Spain during a severe drought in 2005.

HURRICANES AND CYCLONES

There are signs that hurricanes are becoming more frequent and more intense in some regions. During 1996, 1997 and 1999, there were more than twice the average annual number of hurricanes in the USA than there had been in the past 100 years. The most devastating hurricanes in 200 years occurred — Mitch, in 1998, in the Caribbean killed 10,000 people and made three million homeless; in the USA, in 2005, Hurricane Katrina killed more than 1,400 people and the city of New Orleans had to be evacuated.

Activities

Think
1. Use the map to describe the distribution of selected extreme flooding events.
2. Study the graph.
   (a) Describe the trend in economic and insured losses between 1950 and 1998.
   (b) What happened to the proportion of extreme weather events over each successive decade?
   (c) Predict the trend of this graph if global warming and extreme weather events continue to increase.

Design and create
3. Imagine you are a reporter at the Venezuela floods or the Spanish wildfires. Write an article describing the possible weather that led to the extreme event.
4. Research how increased air and water temperatures can affect rainfall and events such as hurricanes. Present this as a magazine article and include illustrations.
In 2006, the Bureau of Meteorology announced that 2005 was the warmest year on record in Australia. The annual mean temperature was 1.09 °C above average. This is the equivalent of many southern Australian towns shifting northward by about 100 kilometres. An increase of 4 °C would mean that temperatures in Melbourne could be similar to those now experienced in Moree, in northern New South Wales.

There were regional differences in the amount of warming and the impact on rainfall. The general trend in 2005 showed increases in average temperatures in all states, and decreases in rainfall, except in Tasmania.

### Potential climate impacts in Australia for various temperature increases

<table>
<thead>
<tr>
<th>Global Temp. rise</th>
<th>Tourism</th>
<th>Water and primary industries</th>
<th>Infrastructure and insurance</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;1 °C</td>
<td>• Regular bleaching of 60% of the Great Barrier Reef&lt;br&gt;• Snow-covered alpine areas shrink by 10 to 40%&lt;br&gt;• Area of montane tropical rainforest in northern Australia decreases by 50%&lt;br&gt;• Vertebrates in the World Heritage Wet Tropics lose half their habitat</td>
<td>• Melbourne’s water supply falls 3 to 11%&lt;br&gt;• Droughts in NSW 70% more frequent and more widespread&lt;br&gt;• Native pasture growth falls by 8% (based on 11% decrease in precipitation)&lt;br&gt;• Cows in NSW Hunter Valley produce 250 to 310 litres less milk a year&lt;br&gt;• 14% of Victoria’s marine invertebrates lose their habitat</td>
<td>• 10 to 20% increase in extreme rainfall in NSW&lt;br&gt;• 25% more days above 35 °C in NT&lt;br&gt;• 18% more days above 35 °C in SA&lt;br&gt;• Peak electricity demand in Adelaide and Brisbane increases by 2 to 5%&lt;br&gt;• Peak electricity demand in Melbourne and Sydney decreases by up to 1%&lt;br&gt;• Demand for natural gas heating in Melbourne decreases</td>
</tr>
<tr>
<td>1–2 °C</td>
<td>• Bleaching of 60 to 80% of the Great Barrier Reef each year&lt;br&gt;• Vertebrates in the World Heritage Wet Tropics lose 90% of core habitat&lt;br&gt;• Loss of 80% of Kakadu freshwater wetlands due to 30 cm sea level rise</td>
<td>• Flows in the Murray–Darling fall 12 to 25%&lt;br&gt;• Melbourne’s water supply falls 7 to 35%&lt;br&gt;• 91% chance of wheat exports falling below current level&lt;br&gt;• $12.4 million/year to manage southward spread of Queensland fruit fly&lt;br&gt;• $5.7 million/year benefit due to reduction in apple moth</td>
<td>• Twice as many people exposed to flooding&lt;br&gt;• Malaria zones spread southward&lt;br&gt;• Population at risk of dengue fever increases from 0.17 million to 0.75–1.6 million&lt;br&gt;• Rise in refugees from Pacific Islands&lt;br&gt;• Peak electricity demand in Adelaide and Brisbane increases by 4 to 10%&lt;br&gt;• Peak electricity demand in Melbourne and Sydney decreases by 1%</td>
</tr>
<tr>
<td>2–3 °C</td>
<td>• Bleaching of 97% of the Great Barrier Reef each year&lt;br&gt;• Victoria’s montane tropical vertebrate species lose 30 to 70% of core habitat</td>
<td>• Flows in the Macquarie River basin (NSW) fall 5 to 35%&lt;br&gt;• Pasture growth slows by 31%&lt;br&gt;• Livestock-carrying capacity falls by 40%</td>
<td>• 10% increase in forest fire danger&lt;br&gt;• 15% increase in 100-year storm tides along eastern Victorian coast&lt;br&gt;• 20 to 30% increase in tropical cyclone rainfall and 5 to 10% increase in wind speed&lt;br&gt;• 17% increase in road maintenance costs across most of Australia</td>
</tr>
<tr>
<td>3–4 °C</td>
<td>• Distribution of Great Barrier Reef species shrinks by 95%&lt;br&gt;• Area of snow-covered alpine area shrinks by 20 to 45%&lt;br&gt;• Area of ‘60-day’ snow cover shrinks by 40 to 95%</td>
<td>• Flows in the Murray–Darling fall 16 to 48%&lt;br&gt;• Australian primary production falls 6%&lt;br&gt;• Eucalyptus lose 55% of their core habitat&lt;br&gt;• Timber yields in SA rise by 25 to 50%, but fall by similar margin in North Queensland and the Top End</td>
<td>• Oceania experiences a net loss of GDP&lt;br&gt;• Dengue fever transmission zone reaches Brisbane and possibly Sydney&lt;br&gt;• Temperature-related deaths of people over 65 rise by 200%&lt;br&gt;• Peak electricity demand increases in Adelaide, Brisbane and Melbourne by 5 to 20%</td>
</tr>
<tr>
<td>&gt;4 °C</td>
<td>• Most Australian vertebrates lose 90 to 100% of their core habitat</td>
<td>• 32% chance of decreased wheat production&lt;br&gt;• 45% chance of wheat crop value being below current level</td>
<td>• 25% increase in extreme rainfall in Victoria&lt;br&gt;• 30% increase in 100-year storm tides along eastern Victorian coast&lt;br&gt;• 150% increase in annual days above 35 °C in SA&lt;br&gt;• Peak electricity demand increases in Adelaide, Brisbane and Melbourne by 9 to 25%</td>
</tr>
</tbody>
</table>
There will be a variety of climate change impacts in Australia, depending on a range of possible global temperature changes. Climate change will impact on natural environments, our water supply, health, agriculture and industry.

**Activities**

**Think**
1. Study the table opposite.
   (a) Outline four possible impacts on Australia’s tourism industry as a result of climate change.
   (b) List three possible benefits of climate change to Australia.
2. Study the temperature and rainfall maps.
   (a) Describe the general pattern of temperature and rainfall experienced in Australia in 2005.
   (b) What type of temperature and rainfall was experienced where you live? How was this different from the normal and historical figures?
   (c) Use an atlas to name two locations experiencing conditions that were:
      - warmer and drier
      - warmer and wetter
      - cooler and wetter.
   (d) Did any locations experience cooler and drier conditions?
3. Describe the potential spread of dengue fever according to two possible futures.

**Teamwork**
4. Divide the class into five groups. Each group will look at the impact of one of the five possible temperature changes on Australia. Use the table and your own ideas to record possible economic, environmental, social and political impacts of this change.

**Use ICT**
5. Visit the website for this book and click on the Rising Sea Levels weblink for this chapter (see 'Weblinks', page vii). Scroll down to ‘Earth’ and zoom in on Australia to see how predicted rises in sea levels will affect locations along the coast. Describe the impact on three coastal locations.

**Worksheets**
6.3 The Great Barrier Reef and climate change
CASE STUDY: GLOBAL WARMING AND AUSTRALIA’S ALPINE REGION

Impacts
Australia’s alpine region forms only about 0.15 per cent of the continent, but is at the forefront of climate change impacts. The CSIRO uses data collected over 35–50 years and applies it to models to predict the impact of further warming on future snow cover. Two scenarios are used: low impact (which the CSIRO expects temperatures will go above); and high impact (which the CSIRO expects temperatures will not go above).

Some possible outcomes as the climate warms include: more precipitation falling as rain rather than snow; an increase in the rate of snow melt and evaporation; a rise in snowlines; a reduction in the number of suitable hours available for snow-making; and shorter ski seasons. The average snowline at present is 1412 metres — this is predicted to rise to between 1440 and 1600 metres by 2020.

### Table: Predicted changes in temperature and precipitation

<table>
<thead>
<tr>
<th>Scenario (Year)</th>
<th>Projected change in temperature (°C)</th>
<th>Projected change in precipitation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low impact (2020)</td>
<td>+0.2</td>
<td>+0.9</td>
</tr>
<tr>
<td>High impact (2020)</td>
<td>+1.0</td>
<td>–8.3</td>
</tr>
<tr>
<td>Low impact (2030)</td>
<td>+0.6</td>
<td>+2.3</td>
</tr>
<tr>
<td>High impact (2050)</td>
<td>+2.9</td>
<td>–24.0</td>
</tr>
</tbody>
</table>

### Predicted changes to snowline, Mount Hotham

<table>
<thead>
<tr>
<th>Date</th>
<th>Present</th>
<th>2020 low impact</th>
<th>2020 high impact</th>
<th>2050 low impact</th>
<th>2050 high impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Jun</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Jun</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Jun</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Jul</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31 Jul</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Aug</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31 Aug</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Sep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Sep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 Oct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 Oct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Predicted changes to snow depth, Mount Hotham

<table>
<thead>
<tr>
<th>Date</th>
<th>Present</th>
<th>2020 low impact</th>
<th>2020 high impact</th>
<th>2050 low impact</th>
<th>2050 high impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Jun</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Jun</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Jun</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Jul</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31 Jul</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Aug</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31 Aug</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Sep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Sep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14 Oct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 Oct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Location of alpine snow areas and selected resorts

Snow making
Artificial snow-making is already used in ski resort areas to extend the ski season. The larger resorts can probably withstand warming for about two decades if they double their snow-making. This costs millions of dollars and uses huge amounts of water and electricity, contributing further greenhouse gases to the environment. It also requires particular conditions below –2 °C, so the opportunity to make snow may be reduced as snow seasons become shorter.
Activities

Understand
1. Describe the location of Australia's alpine region.
2. Outline some of the climate change impacts expected in alpine areas.
3. Which climate scenario is projected to have the greatest impact on Australia's alpine region? Why?
4. Describe the impact of climate change on plant and animal species in alpine areas.

Think
5. Use the graphs to describe the present snow lines for Mount Kosciuszko and Mount Hotham. Describe how these are predicted to change for each projected temperature change.
6. Study the graphs and write a description summarising possible changes to snow depth at Mount Kosciuszko and Mount Hotham in 2020 and 2050. Which mountain will experience the most and least impact on snow depth? Why?

Teamwork
7. Work with another person and brainstorm all the possible impacts climate change will have on the ski and snow resort industry. Suggest ways to overcome or reduce the effect of each impact.
8. Study the diagram outlining possible responses by the ski and alpine resort industry to climate change. Write a short description for each, outlining the advantages and disadvantages.

Alpine ecosystems
Warming by even small degrees will change the distribution of animals and plants and could see alpine ecosystems disappear. Some species of alpine plants, such as the alpine daisy, are already vulnerable and rare in some areas. If they disappear, there will be effects on insects, birds and other animals. The mountain pygmy-possum is already under pressure as its habitat competes with ski resort development. Warming will mean that it will have to compete with other animals that could move into its habitat for food. Feral animals and weeds will also move up the mountains.

Orichora brown butterfly feeding on an alpine daisy

Mountain pygmy-possum
6.8

WHAT ACTIONS CAN STABILISE CLIMATE?

INTERNATIONAL ACTION

Climate change is a global phenomenon. The pollution produced in one country spreads through the atmosphere and affects other countries. Action by only a few countries to reduce greenhouse gases will, therefore, have little impact — it requires international cooperation, especially by the largest polluters.

The main source of human-induced emissions is the burning of fossil fuels for energy. Globally, burning fossil fuels accounts for about 60 per cent of greenhouse gas emissions (in the United States, the figure is 85 per cent). As economic growth continues, emissions are expected to rise, especially in China and India, and developing countries experiencing huge economic growth.

Governments around the world need to act to stop or dramatically slow down greenhouse gas emissions. Types of action include reducing emissions, increasing energy from clean sources, reducing deforestation and changing agricultural practices.

The Kyoto Protocol

In 1992, 170 countries came together at a United Nations conference and agreed to take steps to reduce emissions of greenhouse gases. But, not many countries passed laws to see this through.

In 1997, countries gathered again to develop a policy for stronger action. The result was the Kyoto Protocol, an agreement that sets targets to limit the greenhouse gas emissions of industrialised countries. Developing countries, including China, can sign the Protocol but have no limits imposed on them in the first round of the agreement (from 2008 to 2012). In total, 128 countries agreed to the Kyoto ideal, including Australia and the USA.

The Kyoto Protocol came into effect in February 2005 when it was ratified by most industrialised countries. Australia and the USA, however, did not ratify the Protocol.

HOW DOES IT WORK?

The targets define the amount of greenhouse gases that countries are allowed to emit between 2008 and 2012. This target uses 1990 emissions as a baseline.

To meet these targets, countries must make changes that reduce their level of emissions. They can also meet the targets in two other ways:

• they can carry out projects in other countries that reduce greenhouse gas emissions and offset these reductions against their own target
• companies can buy and sell the right to emit carbon gases. For example, a major polluter, such as a coal power station, is allowed to emit a certain amount of greenhouse gases. If it is energy efficient, and emits less than its limit, it gains carbon credits. It has the right to sell these credits to another company that is having difficulty reducing its emissions.

Companies can also gain credits by investing in projects that reduce greenhouse gases (such as renewable energy), or improve energy efficiency, or that act as carbon sinks (such as tree planting and underground storage of CO₂).

GEOFILE

In 2007, China’s carbon dioxide emissions exceeded those of the USA.
Australia did not ratify the Kyoto Protocol because the Federal Government did not believe it was in the country’s best interest. The Australian economy is heavily based on resources and very reliant on the use of coal. The government believed that jobs and the economy would be at risk if it ratified the agreement. It also believed Australia would be at a disadvantage if developing countries such as China were not given greenhouse gas limits, and their economies were allowed to grow quickly as a result.

Some day, son, all this will be your problem

A political cartoon drawn in February 2005, when the Australian government decided not to ratify the Kyoto Protocol

**CAN THE KYOTO PROTOCOL STOP CLIMATE CHANGE?**

The Kyoto Protocol itself will not stop climate change. Most scientists and governments believe there is a need for much deeper cuts in greenhouse gas emissions — up to 60 per cent by 2050 — to avoid dangerous climate change. The Protocol is seen as a first and important step in getting governments, businesses and individuals to change their behaviour and reduce emissions.

**TAKING PERSONAL ACTION**

Households produce about one-fifth of Australia’s greenhouse gases through their use of transport, household energy and the decay of household waste in landfill. This amounts to about 15 tonnes of CO₂ per household per year. (A tonne of CO₂ would fill one family home.) A few changes to personal lifestyle can make a significant difference in the amount of greenhouse gases a family produces, and at little cost. Other changes, such as building sustainable and energy-efficient homes may cost more initially, but save energy and money in the medium to long term.

* 100 is an emissions level the same as in 1990.

**Greenhouse gas reduction targets**

<table>
<thead>
<tr>
<th>Country</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia</td>
<td>108</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>92</td>
</tr>
<tr>
<td>Canada</td>
<td>92</td>
</tr>
<tr>
<td>Croatia</td>
<td>95</td>
</tr>
<tr>
<td>Czech Republic</td>
<td>92</td>
</tr>
<tr>
<td>European Union</td>
<td>92</td>
</tr>
<tr>
<td>Estonia</td>
<td>92</td>
</tr>
<tr>
<td>Hungary</td>
<td>94</td>
</tr>
<tr>
<td>Iceland</td>
<td>110</td>
</tr>
<tr>
<td>Japan</td>
<td>94</td>
</tr>
<tr>
<td>Latvia</td>
<td>92</td>
</tr>
<tr>
<td>Liechtenstein</td>
<td>92</td>
</tr>
<tr>
<td>Lithuania</td>
<td>92</td>
</tr>
<tr>
<td>Monaco</td>
<td>92</td>
</tr>
<tr>
<td>New Zealand</td>
<td>100</td>
</tr>
<tr>
<td>Norway</td>
<td>101</td>
</tr>
<tr>
<td>Poland</td>
<td>92</td>
</tr>
<tr>
<td>Romania</td>
<td>92</td>
</tr>
<tr>
<td>Russian Federation</td>
<td>100</td>
</tr>
<tr>
<td>Slovakia</td>
<td>92</td>
</tr>
<tr>
<td>Slovenia</td>
<td>92</td>
</tr>
<tr>
<td>Switzerland</td>
<td>92</td>
</tr>
<tr>
<td>Ukraine</td>
<td>100</td>
</tr>
<tr>
<td>United States of America</td>
<td>93</td>
</tr>
</tbody>
</table>

**European Union commitments**

<table>
<thead>
<tr>
<th>Country</th>
<th>Commitments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>–13%</td>
</tr>
<tr>
<td>Belgium</td>
<td>–7.5%</td>
</tr>
<tr>
<td>Denmark</td>
<td>–21%</td>
</tr>
<tr>
<td>Finland</td>
<td>0%</td>
</tr>
<tr>
<td>France</td>
<td>0%</td>
</tr>
<tr>
<td>Germany</td>
<td>–21%</td>
</tr>
<tr>
<td>Greece</td>
<td>+25%</td>
</tr>
<tr>
<td>Ireland</td>
<td>+13%</td>
</tr>
<tr>
<td>Italy</td>
<td>–6.5%</td>
</tr>
<tr>
<td>Luxembourg</td>
<td>–28%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>–6%</td>
</tr>
<tr>
<td>Portugal</td>
<td>+27%</td>
</tr>
<tr>
<td>Spain</td>
<td>+15%</td>
</tr>
<tr>
<td>Sweden</td>
<td>+4%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>–12.5%</td>
</tr>
</tbody>
</table>

* Kyoto Protocol greenhouse gas targets

**AUSTRALIA’S POSITION**

Australia did not ratify the Kyoto Protocol because the Federal Government did not believe it was in the country’s best interest. The Australian economy is heavily based on resources and very reliant on the use of coal. The government believed that jobs and the economy would be at risk if it ratified the agreement. It also believed Australia would be at a disadvantage if developing countries such as China were not given greenhouse gas limits, and their economies were allowed to grow quickly as a result.
The Australian Conservation Foundation has suggested a 10-point plan (see below) that every Australian household can follow to reduce its level of greenhouse gas pollution.

**SUSTAINABLE ENERGY**

Global warming is happening, but the human activities that contribute to it by producing greenhouse gases are not irreversible. People can make a difference.

**Alternative energy**

Alternatives to using fossil fuels to generate more sustainable energy have been developed and used to various extents in different parts of the world. Four of these resources are wind, sun and water and geothermal energy. These, and others, are described further in the illustration.

**Solar panels in the desert**

A series of 1900 curved mirrors, computer controlled to follow the sun, concentrate the rays of the sun onto the top of a 100-metre-high tower. Molten salt heated to 560°C is stored in the tower. The salt slowly releases the heat that is then used to run a generator.

**Wind power**

Modern windmills, hollow towers with turbines at the top, can be used to generate energy from the wind. A generator converts the spinning motion into electricity. Wind turbines need to be located in areas where the wind blows at a constant speed. Reliably strong winds that would enable electricity to be generated in this way exist in many parts of the world. Opponents claim wind farms would be noisy and visually polluting.

**Geothermal energy**

The Earth has a hot molten core. At appropriate locations this heat can be harnessed: bore holes are drilled down to hot rock through which water can be pushed down. The steam created can be brought to the surface where it is used to power turbines and create electricity. Australia has some of the best sites in the world for this type of geothermal power generation.

**Wave power**

This is a floating platform that converts wave energy to electricity. The platform contains three air chambers in which the water level rises and falls as waves pass through the platform. This forces the air to pass over a turbine, thereby creating electricity.
Geosequestration

Geosequestration is the geological storage of carbon dioxide in deep rock formations. CO₂ would be captured from a power station and pumped into underground storage about 2 kilometres beneath the Earth’s surface. This option could substantially reduce greenhouse gas emissions. There are some concerns about this process related to possible leaks of CO₂ from the ground. CO₂ is heavy and can suffocate people and animals. The cost of geosequestration is very high and may increase the price of electricity from coal-fired power stations.

Activities

Think
1. Outline why climate change is a global problem. Why is international cooperation required to overcome this problem?
2. Describe the development of the Kyoto Protocol. Why are industrialised, and not developing, countries given targets? Do you think this should be the case? Justify.
3. What is a carbon credit? Give two examples. How can carbon credits be traded?
4. Explain Australia’s reasons for not ratifying the Kyoto Protocol. Do you think Australia should have ratified this agreement?
5. Study the sustainable energy methods on these pages. In groups, brainstorm the advantages and disadvantages of each to meet energy needs and reduce greenhouse gases.

Design and create
6. Write an imaginative story describing the world’s climate in 2050 and what has happened to greenhouse gas emissions. Include examples of alternative energy sources.

Use ICT
7. Visit the website for this book and click on the Greenhouse Calculator weblink for this chapter (see ‘Weblinks’, page vii). Complete the greenhouse calculator. What action can your family take to reduce greenhouse gases?

Worksheets
6.4 Wind, hydro or nuclear — alternative energy sources
6.5 Home of the future
DIFFERENT VIEWPOINTS

The issue of global warming has created many special interest groups, each arguing their particular case and own solution. The discussions and decision-making process are examples of active citizenship. Some possible views are presented below.

**Federal Minister for Energy and the Environment**

My government accepts the science of global warming, but does not think the Kyoto Protocol is the way to go. Without participation from the US (which is responsible for 25 per cent of global emissions), and developing countries — especially China and India who have fast-growing economies — the Protocol will not work. Australia cannot afford to be placed in a position that weakens its economic position — this will happen if we stop using coal and use more expensive energy sources.

When people need to solve a problem, they usually can. We need to place our efforts into solutions to reduce greenhouse gas emissions such as geosequestration and clean carbon technologies. We are working with big polluters who are voluntarily reducing emissions and will create incentives for the renewable energy sector. We are also looking at other possibilities such as building nuclear power stations, which will not produce any greenhouse gases.

**Federal Opposition Minister for Energy and the Environment**

Global warming is both a challenge and an opportunity. Although the Kyoto Protocol has shortcomings, I think it should be ratified by Australia. It is an important step in making sure that rich countries — who created the problem of global warming — are brought to account and encouraged to make radical changes to prevent greenhouse pollution. We stand to lose money by not being part of the Protocol — the European Union already has an emissions and carbon trading scheme worth billions of dollars.

We need a national greenhouse policy that sets targets that will reduce emissions by at least 60 per cent by 2050. Big profits can be made from energy-saving innovation. We need to be part of the multi-billion dollar emerging carbon-friendly technologies and put money into research and development. Otherwise, our best scientists and brightest ideas may move overseas where money is already being invested in alternative technologies.

In addressing this problem, winners and losers will be created. There will be a shift in which businesses will be successful — we no longer have blacksmiths, but alternative businesses and technologies were created to meet the needs that they once served. The same will be true here — the coal industry may not be able to dominate electricity generation, but there will be a shift to alternative energies. This has occurred in the past with many other industries — textiles, sugar etc. It is how we manage the shift that will be important.

**Environmental groups’ representative**

The Kyoto Protocol is designed to put a price on pollution, where companies buy and sell the right to emit carbon emissions. This will help companies to rethink almost everything they do — reducing wastage of electricity from lights and appliances; expanding renewable energies; and constructing energy-efficient buildings.

Unfortunately, governments and businesses do not always look at the big picture, but often have short-term goals. If they introduce higher taxes or prices to combat global warming, governments may lose votes and, potentially, elections. If businesses cut emissions or divert money to new technologies, they may not make as much profit and may lose shareholders. By selling coal to non-target emission countries, Australia still gets to earn money without needing to consider greenhouse gas emissions. We cannot wait for the issue to be solved for us. We can all make small changes to reduce global warming, with little effect on our lifestyles.

Australia could be playing a leadership role and creating opportunities by developing alternative strategies. It is time for all governments to admit the scale of the problem and develop policies to tackle it. We need long-term wisdom, not short-term political and economic gain. Consider what the cost will be if we do nothing.
Teamwork
1. Use the roles outlined to conduct the inaugural meeting of the Australian Climate Change Initiative. Choose six people to represent the roles and a further six to research each opinion further. The rest of the class will represent the media and will be allowed question time at the end of the presentation. Each student will write an eight-point summary of what the initiative should be.

2. Imagine it is 2012 and the Kyoto targets have been met. Greenhouse gases are continuing to rise because of pollution from developing countries that have expanded their economies. Work with two other people to develop Kyoto Protocol 2, outlining general objectives and specific action that needs to occur.

Activities

Worksheets
6.6 The nuclear debate
GLOBAL WARMING AND CLIMATE CHANGE

1. Summarise the spatial interaction between people and climate change by referring to examples in this chapter. Include the impact of people on the environment and how the environment affects people.

2. Use examples in the chapter to describe the impact of climate change at the following scales: local, national, regional and global.

GLOBAL WARMING PATTERNS

1. Study the scatter graph below.
   (a) List the three countries producing the:
      - highest CO₂ per capita
      - lowest CO₂ per capita.
   (b) List the three countries with the:
      - highest GDP per capita
      - lowest GDP per capita.
   (c) Describe the general relationship between CO₂ production and GDP per capita shown by the graph.
   (d) List three anomalies to this pattern.

2. Draw a graph to show the data in the table below.
   (a) What is the relationship between population growth and CO₂ emissions?
   (b) How can the differences between developed and developing countries be explained?

Regional predictions for CO₂ emissions and population growth 1985–2100

<table>
<thead>
<tr>
<th>Year</th>
<th>Developing world</th>
<th>Developed world</th>
<th>World total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>3.64</td>
<td>1.23</td>
<td>4.87</td>
</tr>
<tr>
<td>2025</td>
<td>6.76</td>
<td>1.43</td>
<td>8.19</td>
</tr>
<tr>
<td>2100</td>
<td>8.95</td>
<td>1.47</td>
<td>10.42</td>
</tr>
</tbody>
</table>

CO₂ emissions per capita

<table>
<thead>
<tr>
<th>Year</th>
<th>Developing world</th>
<th>Developed world</th>
<th>World total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>0.59</td>
<td>3.13</td>
<td>1.23</td>
</tr>
<tr>
<td>2025</td>
<td>1.01</td>
<td>3.88</td>
<td>1.51</td>
</tr>
<tr>
<td>2100</td>
<td>1.58</td>
<td>8.13</td>
<td>2.50</td>
</tr>
</tbody>
</table>

Total CO₂ emissions *

<table>
<thead>
<tr>
<th>Year</th>
<th>Developing world</th>
<th>Developed world</th>
<th>World total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>2.15</td>
<td>3.85</td>
<td>6.0</td>
</tr>
<tr>
<td>2025</td>
<td>6.85</td>
<td>5.55</td>
<td>12.4</td>
</tr>
<tr>
<td>2100</td>
<td>14.15</td>
<td>11.95</td>
<td>26.1</td>
</tr>
</tbody>
</table>

* Including emissions from deforestation and cement production

3. Why do you think the Kyoto Protocol has initially set greenhouse gas emissions only for industrialised countries?

THE IMPACT OF CLIMATE CHANGE

1. List current evidence that shows climate change is already occurring.
2. Conduct research into the effect of climate change on animals and plants, including evidence for the change in seasons and the spread of disease.
3. Study the map of Australia below.
   (a) Describe the general pattern for 2005 shown by the map.
   (b) Which state/territory experienced the greatest change?
   (c) Which state experienced the only increase in rainfall?
   (d) List some possible impacts of this trend for two regions in Australia.

4. In Australia, how will the number of days with snow cover be affected by the climate changes that the CSIRO expects to occur?

5. List three ways the ski industry might respond to these projections.

6. Visit the website for this book and click on the Bangladesh weblink for this chapter (see ‘Weblinks’, page vii). Study the diagram of the potential impact of a rise in sea level on Bangladesh. Describe this impact.

7. Explain how people living in low-lying areas and businesses such as the ski industry, are ‘frontline victims’ of global warming.

**ACTION TO TACKLE CLIMATE CHANGE**

1. Discuss the problem of tackling a global problem such as climate change. How has the Kyoto Protocol begun this process?

2. Make a list of actions governments can take to reduce greenhouse gas emissions. Identify the advantages and disadvantages of each.

3. Identify the action individuals can take to reduce greenhouse gas emissions. Make a list of five things your family and school can do to reduce global warming.

4. Visit the website for this book and click on the CO₂ Calculator weblink for this chapter (see ‘Weblinks’, page vii) to complete a more complex CO₂ calculator. You may like to work with another student to complete this.

   *Note:* This is a UK site and you will need to use kilometres and Australian dollars.