2 GLOBAL CLIMATE—VULNERABILITY AND RESILIENCE

Four key concepts influence these issues: places, power, processes and possibilities. There are positive aspects of change, as well as negative ones. It is necessary to accept responsibility for the causes, and to seek solutions and manage the issues.

You should be able to show:

- ✔ how natural and human **processes** affect the global energy balance;
- ✔ how the effects of global climate change on **places**, societies and environmental systems;
- ✔ that there are **possibilities** for responding to climate change and **power** over the decision-making process.

2.1 THE CAUSES OF GLOBAL CLIMATE CHANGE

- **Albedo** – the amount of incoming solar energy reflected back into the atmosphere by the Earth's surface.
- **Anthropogenic** – human-related processes and/or impacts.
- **Energy balance** – the balance between incoming short-wave radiation and outgoing short-wave and long-wave radiation.
- **Enhanced greenhouse effect** – the increasing amount of greenhouses gases in the atmosphere, as a result of human activities, and their impact on atmospheric systems including global warming.
- **Global warming** – the increase in temperatures around the world that has been noticed since the 1960s, and in particular since the 1980s.
- **Greenhouse effect** – also called the natural greenhouse effect, this is the process by which certain gases (water vapour, carbon dioxide, methane

You should be able to show how natural and human processes affect the global energy balance:

- ✔ The atmospheric system, including the natural greenhouse effect and energy balance;
- ✔ Changes in the global energy balance, and the role of feedback loops;
- ✔ The enhanced greenhouse effect and international variations in greenhouse gas sources and emissions, in relation to economic development, globalization and trade.

The atmospheric system

The natural greenhouse effect and the enhanced greenhouse effect (global warming)

The natural greenhouse effect is the process by which certain gases (greenhouse gases) allow short-wave radiation from the Sun to pass through the atmosphere but trap an increasing proportion of outgoing long-wave radiation from the Earth. This radiation leads to a warming of the atmosphere. The greenhouse effect is a good thing, for without it there would be no life on Earth. For example, the Moon is an airless planet that is almost the same distance from the Sun as the Earth. However, daytime temperatures on the Moon may reach as high as 100°C, whereas by night they may be –150°C. Average temperatures on the Moon are about –18°C compared with about 15°C on Earth. The Earth's atmosphere therefore raises temperatures by about 33°C.

There are a number of greenhouse gases. Water vapour accounts for about 95% of greenhouse gases by volume and for about 50% of the greenhouse effect. However, the gases mainly implicated in global warming are carbon dioxide, methane and chlorofluorocarbons.

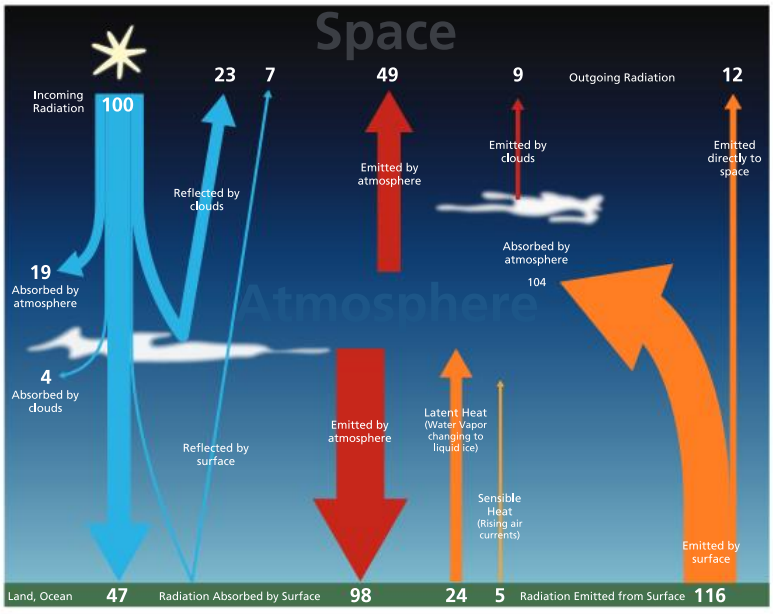
Carbon dioxide (CO_2) levels have risen from about 315 parts per million (ppm) in 1950 to over 400 ppm in 2015, and are expected to reach 600 ppm by 2050. The increase is due to human activities: burning fossil fuels (coal, oil and natural gas) and land-use changes such as deforestation. Deforestation of the tropical rainforest is a double blow, since it not only increases atmospheric CO_2 levels but it also removes the trees that convert CO_2 into oxygen. Carbon dioxide accounts for about 20% of the greenhouse effect but an increased proportion of the enhanced greenhouse effect.

Methane is the second-largest contributor to global warming, and its presence in the atmosphere is increasing at a rate of 1% per annum. It is estimated that cattle convert up to 10% of the food they eat into methane and emit 100 million tonnes of methane into the atmosphere each year. Natural wetland and paddy fields are other important sources: paddy fields emit up to 150 million tonnes of methane annually, while, as global warming increases, bogs trapped in permafrost will melt and release vast quantities of methane.

The enhanced greenhouse effect is the impact of increasing levels of greenhouses gases in the atmosphere as a result of human activities. It is often referred to as global warming. Global climate change refers to the changes in the global patterns of rainfall and temperature, sea level, habitats and the incidence of drought, floods and storms, resulting from changes in the Earth's atmosphere, believed to be caused mainly by the enhanced greenhouse effect.

The increase in the world's greenhouse gases is linked to industrialization, trade and globalization. As industrialization has increased, so too has atmospheric CO_2. Many LICs and NICs are actively industrializing and adopting a consumer culture. Industrial activity among the NICs has the potential to add to atmospheric CO_2. Nevertheless, the per-capita emissions in HICs are responsible for much of the growth in atmospheric CO_2.

Changes in the global energy balance



▲ **Figure 2.1.1.** The Earth's energy balance

Assessment tip

Be very clear about the difference between the *natural* greenhouse effect (which is a good thing and vital for life) and the *enhanced* greenhouse effect (which is related to human activities and is not so good for everyone).

and chlorofluorocarbons (CFCs)) allow short-wave radiation from the Sun to pass through the atmosphere and heat up the Earth, but trap a proportion of long-wave radiation from the Earth. This radiation leads to a warming of the atmosphere.

- **Feedback** – the ways that changes in an environment may be accelerated or modified by the processes operating in a system.
- **Positive feedback** – changes in a system that lead to greater deviation from the original condition (also known as cumulative causation or a vicious circle).
- **Negative feedback** – changes in a system that occur and lead to other changes, but eventually the whole system stabilizes.

Test yourself

2.1 According to figure 2.1.1, **determine** the amount of the incoming solar radiation that is absorbed by the Earth's surface. [1]

2.2 Outline the ways in which solar radiation differs from the Earth's radiation. [2]

2.3 Compare the incoming sources of energy in the atmosphere with the outgoing energy sources. [2]

2.4 Explain two processes in which global energy is balanced. [2+2]

Assessment tip

Do not confuse the ozone layer with the greenhouse effect—they are very different. The ozone layer protects the Earth from harmful ultraviolet radiation whereas the greenhouse effect is responsible for raising the temperature on Earth and making life possible. (Ozone is a minor greenhouse gas, but its contribution to the greenhouse effect is very small.)

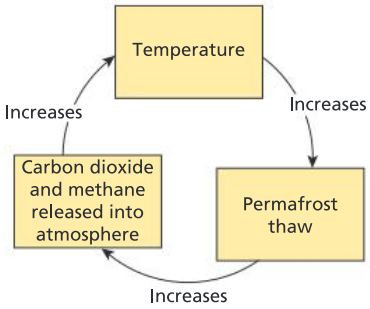
Test yourself

2.5 Distinguish between the natural greenhouse effect and the enhanced greenhouse effect. [2]

2.6 Briefly **explain** how global dimming reduces some of the impact of the enhanced greenhouse effect/global warming. [2]

Assessment tip

Many students get confused about positive and negative feedback. The terms do not mean good or bad. Positive feedback means that the feature continues to change, whereas negative feedback means that it stops changing, that is, it adapts to a new circumstance.



▲ **Figure 2.1.2.** A positive feedback mechanism involving methane and enhancing climate change

Content link

The impact of global climate change on extreme environments is discussed in option C.4.

Test yourself

2.9 Suggest how greenhouse gas emissions are likely to change over the period between now and 2040. [2]

Solar radiation variations

There have been many variations in solar radiation, and these have caused changes in the Earth's climate over the geological past. However, variations in solar radiation have not been significant in recent warming. Since the 1970s, fluctuations in solar radiation have been measured by satellites. Solar activity has been declining since the 1960s. In addition, there has been no correlation between sunspot activity and global warming. However, some of the variation in solar radiation reaching the Earth's surface can be put down to periodic volcanic activity, such as the eruption of Mt Pinatubo in the Philippines in 1991, and human-caused pollution, causing global dimming.

Feedback loops

▼ **Table 2.1.1.** Some albedo values for terrestrial surfaces

Surface	Albedo (%)
Water (Sun's angle over 40°)	2–4
Water (Sun's angle less than 40°)	6–80
Fresh snow	75–90
Old snow	40–70
Dry sand	35–45
Dark, wet soil	5–15
Dry concrete	17–27
Black road surface	5–10
Grass	20–30
Deciduous forest	10–20
Coniferous forest	5–15
Crops	15–25
Tundra	15–20

Source of data: Adapted from Barry, R. and Chorley, R., *Atmosphere, weather and climate*, Routledge (1998)

Test yourself

2.7 Briefly **explain** how albedo changes may change lead to changes in the energy balance. [2]

2.8 Suggest how the release of methane can lead to feedback loops associated with changes in the global energy balance. [2]

The enhanced greenhouse effect and international variations in greenhouse gas sources and emissions

In 1990, total CO_2 emissions were about 22 billion tonnes. Europe and Eurasia produced most of the CO_2 emissions, about 8 billion tonnes, followed by North America, with about 6 billion tonnes. China only produced about 2 billion tonnes, and the rest of Asia was similar. By 2016 the Asia-Pacific region produced almost half of global emissions, up from 25% in 1990. China alone produced about 10 billion tonnes of CO_2, Europe and Eurasia's output had fallen to around 6 billion tonnes, and North America had remained steady overall.

2.2 THE CONSEQUENCES OF GLOBAL CLIMATE CHANGE

You should be able to show the effects of global climate change on places, societies and environmental systems:

- ✔ Climate change and the hydrosphere, atmosphere and biosphere;
- ✔ Impacts of climate change on people and places, including health hazards, migration and ocean transport routes.

Climate change and the hydrosphere, atmosphere and biosphere

Water stored in ice and oceans, and changing sea levels

Europe's glaciers lost around 25% of their mass between 2006 and 2014.

- **Sea levels are expected to rise by one metre by 2100.**
- There has been a 13.3% decrease in Arctic sea ice each decade since 1980.
- By 2040, summer sea ice is likely to be limited to the northern coasts of Canada and Greenland.
- By 2080, arctic summer sea ice is expected to disappear completely.
- By 2100, arctic temperatures will be as high as 7°C above pre-industrial levels.

Carbon stored in ice, oceans and the biosphere

Glaciers store carbon derived from primary production on the glacier and deposition of materials such as soot or by-products of the combustion of fossil fuels. Measurements in Greenland and Antarctica suggest that the amount of organic carbon lost from glaciers will increase by 50% between 2015 and 2050. That equates to roughly half of the total amount of carbon carried by the Mississippi River to the ocean each year.

Permafrost contains vast amounts of carbon. When permafrost melts, carbon is released either as carbon dioxide or as methane, stored in frozen form. If permafrost continues to melt, some 190 gigatonnes of carbon could be released into the atmosphere by 2200.

Methane released from seafloor permafrost could also contribute to ocean acidification. Currently about 25% of human-produced carbon dioxide emissions are absorbed by the oceans. Carbon dioxide reacts with seawater to make it more acidic. This change affects many marine organisms.

Incidence and severity of extreme weather events including drought

Trends towards extreme climate change are likely to increase. This includes the weakening of the North Atlantic Drift (NAD) and the meandering behaviour of the jet stream. Increased flows of freshwater from Greenland's ice sheet caused a 30% slowdown of the NAD between 2009 and 2010. A complete switch-off of the NAD could reduce land temperatures in the UK, Greenland, Iceland and Scandinavia by 9 °C.

- **Saltwater intrusion** – the contamination of groundwater by seawater.
- **Biome** – a large-scale naturally occurring ecosystem, identifiable on a global or regional scale.
- **Ecosystem services** – the products and services provided by ecosystems, such as climate regulation, flood regulation, oxygen, food, timber and water.
- **Ecological threshold** – the point at which there is an abrupt change in an ecosystem properties or quality.
- **Resilience** – the ability of a population or a human or natural system to absorb change without having to make a fundamental change.
- **Threshold (or tipping points)** – the critical level at which change is irreversible.
- **Vulnerability** – the degree to which a human or natural system is susceptible to, and unable to cope with, the adverse impacts of climate change.

Content link

Changes in sea levels are also discussed in option B.2.

Assessment tip

Carbon dioxide (CO_2) and methane (CH_4) have dissimilar names, but both contain carbon, and both are greenhouse gases.

Concept link

PLACES: All places will be affected by global climate change, with some places experiencing benefits, and others will be negatively impacted. The natural and human worlds are changing, and places at varying levels of development will suffer contrasting impacts. For example, some places may suffer environmental degradation and populations will relocate to another place, while others may experience rising food prices due to a reduction in the agricultural yield in their country, or perhaps elsewhere in the world.

Due to higher temperatures, there may be an increase in cyclone activity (including hurricanes). Increased evaporation may potentially lead to more frequent and intense storm activity, particularly in coastal areas.

Wildfires have become more common in high latitudes. As firefighting in remote areas is difficult, many of these fires burn for months, adding carbon to the atmosphere.

Spatial changes in biomes, habitats and animal migration patterns

Tropical forests are beginning to die back due to the increased severity and frequency of droughts. In 2005 and 2010, two severe droughts led to the Amazon rainforest emitting more carbon than it absorbed. Although Indonesia's forests are only 20–25% of the size of the Amazon rainforest, forest fires there emit massive amounts of carbon as many of the forests grow on carbon-rich peat.

Climate change can affect where species live, their food supply and the timing of biological events. Projected climate change may increase the extinction of species in sensitive areas. Climate change may affect the capacity of ecosystems to survive extreme events, such as fires, droughts and floods. Mountain and arctic ecosystems are especially vulnerable, as species have fewer places in which to take refuge. Many fish species have migrated to higher latitudes and warmer conditions.

▲ **Figure 2.2.1.** Global climate change is leading to the drying of many soils

Warming may force species to higher altitudes or latitudes. As sea levels rise, saltwater intrusion into freshwater may adversely affect some species. As rivers warm, warm water fish species are replacing coldwater species such as trout and salmon. The coldwater species are projected to lose around 50% of their habitat by 2080.

The impact of climate change can pass up through the food web. Reductions in sea ice in the Arctic lead to a decline in the algae that are eaten by zooplankton, and in turn by cod. Cod are an important food source for seals, which are fed on by polar bears.

Content link

Future possibilities in sustainable food production are discussed in option F.4.

Agricultural crop yields, limit of cultivation and soil erosion

- In some areas, crop yields will reduce due to warmer and drier conditions. In sub-Saharan Africa, an increase of 1.5–2.0°C will lead to a decrease of millet and sorghum areas by 40–80%.
- The limits of cultivation may move further north in North America and Russia due to rising temperatures in the tundra, which will lead to the possibility of agriculture and increasing growing seasons.
- Soil erosion, land degradation and desertification has increased the size of the Sahara Desert during the 20th century.

Impacts of climate change on people and places, including health hazards, migration and ocean transport routes

Certain population groups are more vulnerable to climate change. These include the poor, young, elderly and sick, and people living in vulnerable areas. Low-lying coastal areas are at risk from a variety of threats such as flooding, saltwater intrusion and storm surges. Cities are also vulnerable due to the large concentrations of people there.

Cities increase the risk of heatwaves due to the formation of urban microclimates and the heat-island effect. Many cities have an aging infrastructure, including drainage and sewer systems, flood protection schemes, transport and power supply systems.

Indigenous populations are vulnerable for many reasons. They:

- rely on the natural environment for food and cultural practices, as well as for income
- live in isolated and/or low-income communities
- have high rates of uninsured individuals
- have high rates of existing health risks compared to other groups.

Assessment tip

Try to get across the complexity of the impact of climate change on human health. For example, people's health will not only be affected by the spread of diseases such as malaria, but many people will be affected by severe dehydration due to prolonged drought, and fatigue due to high temperatures, which may lead to an increase in illness (morbidity) and death rates (mortality).

Diseases such as malaria will become more common as temperatures rise. This is because the mosquitoes need temperatures above 20°C in order to breed.

Around 60 million people in the Indus and Brahmaputra river basins rely on glacial meltwater for their water supply. With glaciers melting faster, there is likely to be an increase in the short-term flow of water, but a long-term decrease as the sources of water disappear.

Considering all of the information above, planners are anticipating a large-scale increase in the number of climate-change refugees. In some locations, such as the Pacific island of Kiribati, some people have already been forced to leave their homes due to rising sea levels and saltwater intrusion into freshwater.

Transport routes, such as the north-west passage from the USA to Arctic Canada, may open up, as well as the seas to the north of Siberia. Not only would this allow for year-round transport, it may also facilitate oil exploration.

Assessment tip

It is a common misconception that only the poor will be affected by climate change. Although certain groups are more vulnerable to climate change (for example, poor, indigenous populations and refugees), many middle- and high-income people will also be affected. Food prices will rise, food scarcity will increase, insurance premiums will increase, and the likelihood of water shortages will also increase.

Content link

Managing climate change in urban environments is discussed in option G.4.

Test yourself

2.10 Explain how climate change may affect **(a)** agriculture and **(b)** ecosystems. [3+3]

2.3 RESPONDING TO GLOBAL CLIMATE CHANGE

- **Adaptation** – initiatives and measures to reduce the vulnerability of human and natural systems to climate change.
- **Mitigation** – attempts to reduce the causes of climate change.
- **Risk** – the probability of a hazard event causing harmful consequences (expected losses in terms of death, injuries, property damage, economy and environment).
- **Geoengineering** – schemes designed to tackle the effects of climate change directly, usually by removing CO_2 from the air or limiting the amount of sunlight reaching the planet's surface (also known as climate engineering).
- **Stakeholder** – a person, community and/or an organization that has an interest in something, For example, stakeholders in climate change might include farmers, oil companies, residents in low-lying coastal areas and so on.

Test yourself

2.11 Using examples, briefly **explain** how vulnerability varies with **(a)** location, **(b)** wealth, **(c)** gender, **(d)** age, **(e)** education and **(f)** risk perception. [2+2+2+2+2+2]

Test yourself

2.12 Suggest why London is vulnerable to flooding. [2]

2.13 Suggest why Cape Town is running out of water. [2]

2.14 Outline the measures that have been taken to reduce water consumption in Cape Town. [3]

You should be able to show examples of possibilities for responding to climate change and power over the decision-making process:

- ✔ Disparities in exposure to climate-change risk and vulnerability, including variations in people's location, wealth, social differences (age, gender and education) and risk perception;
- ✔ Government-led adaptation and mitigation strategies for global climate change;
- ✔ Civil society and corporate strategies to address global climate change.

Disparities in exposure to climate-change risk and vulnerability

There are many disparities in exposure to climate change, such as by location, wealth, gender, age, education and risk perception.

London's exposure to climate-change risk and vulnerability

London is already vulnerable to extreme weather, namely floods, droughts, heatwaves and very cold weather. It is likely that in a warming world, London will experience warmer, wetter winters and hotter, drier summers. Very cold winters will still occur, although they will become less frequent. Sea level will continue to rise for centuries.

London is vulnerable to flooding from many sources: tidal flooding from the North Sea, river flooding from the Thames and heavy rainfall events. Some 15% of the city lives on a floodplain. That means that over 1.25 million people, more than 480,000 properties and a great deal of key infrastructure (transport links, schools and hospitals) are at risk of flooding.

Drought is likely to increase in future due to decreased summer rainfall and increased demand for water. Although there were droughts in 2003 and 2006, and floods in 2000 and 2002, London was able to deal with them.

Climate change and Cape Town

Cape Town is running out of water. By January 2018, following three dry years, dam levels of usable water were down to 17% of capacity and the authorities were preparing to shut off residential supplies. This would have left around 4 million residents reliant on standpipes. In June 2018 heavy rains refilled Cape Town's dam to 43% capacity, and Day Zero was put back until sometime in 2019.

Given the huge disparities in South African society, there is plenty of scope for resentment. Some are sharing tips on how to wash in a bucket and reuse the contents. Farms and hotels have halved water use. Others are exceeding the 50 litres per day recommended by the city's authorities, emptying supermarket shelves of bottled water. Thus, water usage is still too high and Cape Town may become the first major city in the developed world that runs out of water.

South Africa's weather services have told politicians that their models no longer work and their long-term climate-change predictions have arrived 10 years early.

Investments that would have failed cost-benefit analyses 10 years ago—expensive desalination plants in Cape Town's case—now look essential.

Government-led adaptation and mitigation strategies for global climate change

Mitigation strategies for global climate change

Mitigation refers to attempts to reduce the causes of climate change. Many of these are shown in table 2.3.1.

National and international methods	Individual methods
• Control the amount of atmospheric pollution • Geoengineering • Develop carbon-capture schemes • Develop renewable energy sources • Set limits on carbon emissions • Ocean fertilization • Carbon-trading schemes • Carbon-offset schemes • Introduce carbon taxes	• Use public transport • Use locally produced foods • Use energy-efficient products • Turn off appliances when not in use • Reduce heating by insulating buildings • Use double- or triple-glazed windows • Turn off taps when not in use • Walk more or ride a bicycle • Use less heating/air-conditioning

▲ **Table 2.3.1.** Methods of climate change mitigation

Government-led adaptation strategies for global climate change

Adaptation refers to initiatives and measures to reduce the vulnerability of human and natural systems to climate change.

There are many problems related to climate change, and many possible ways of adapting to them. Some of these are shown in table 2.3.2.

Climate-change risks	Potential adaptation strategies
• Flooding • Disease • Sea-level rise • Contaminated water • Dehydration • Drought • Famine/food shortages • Over-heating	• Early-warning systems • Emergency shelters • New forms of agriculture • Genetic engineering/high-yielding varieties of crops (HYVs) • Irrigation • Sea walls • Mosquito nets • Desalination • Migration

▲ **Table 2.3.2.** Risks of climate change and possible adaptation strategies

Civil society and corporate strategies to address climate change

WWF Australia

Australia is vulnerable to climate change. Most of its cities are coastal and low-lying. Extreme weather events have led to floods, droughts and fires. The Great Barrier Reef has suffered from coral bleaching. One in six species is threatened with extinction. Ocean acidification is threatening shellfish as well as coral. Water shortages and agricultural change are also each an increasing problem.

2.15 Briefly **explain** the terms "desalination" and "cost-benefit analysis". [2+2]

2.16 Outline one advantage and one disadvantage of desalination for Cape Town. [2+2]

2.17 Briefly **explain** why London should be better able to adapt to climate change than Cape Town. [2]

Test yourself

2.18 Define the terms **(a)** carbon-offset schemes, **(b)** geo-engineering, **(c)** carbon capture and **(d)** ocean fertilization. [1+1+1+1]

Test yourself

2.19 Identify the likely adaptation strategies that may be used for **(a)** sea-level rise, and **(b)** famine/food shortages. [2+2]

• **Civil society** – any organization or movement that works between the household, the private sector and the state to negotiate matters of public concern. Civil societies include non-governmental organizations (NGOs), community groups, trade unions, academic institutions and faith-based organizations.

Assessment tip

Try to keep up to date. Changes in government can have a significant impact on climate-change policy, for example. In 2017, the US president, Donald Trump, signed deals to increase production of fossil fuels, whereas the Chinese president, Xi Jinping, indicated that China would like the world to increase production and use of clean energy.

Content link
The success of civil societies in raising awareness of environmental risks is explored further in unit 6.3.

As a civil society, WWF Australia is committed to:

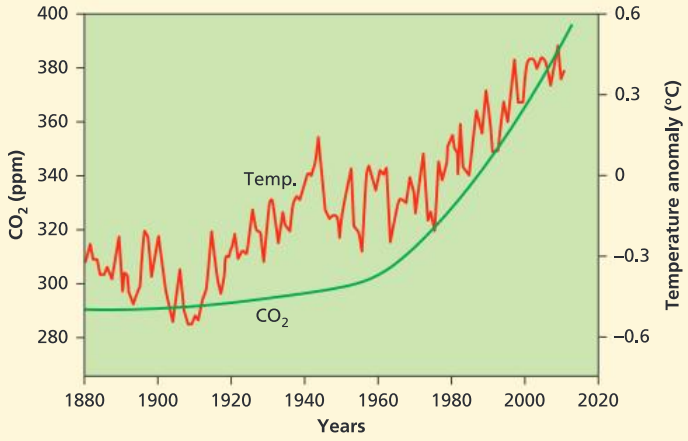
- limiting global warming to 1.5°C above pre-industrial levels by the end of the century
- achieving net-zero carbon pollution in Australia before 2050
- achieving 100% renewable energy in Australia before 2050, including 100% renewable electricity before 2035.

Test yourself

2.20 Evaluate the role of civil societies in the fight against climate change. [5]

QUESTION PRACTICE

a) Study the following figure, which shows changes in atmospheric CO_2 and mean surface temperature since 1880.



i) **Estimate** the increase in atmospheric CO_2 (ppm) between 1960 and 2015. [1]

ii) **Estimate** the change in temperature between 1960 and 2015. [1]

b) **Draw** a labelled diagram to show the main features of the greenhouse effect. [4]

c) **i)** **Suggest one** reason why predictions for global climate change vary. [2]

ii) **Explain one** natural cause of climate change. [2]

Essay

"Climate change impacts will be greatest for places with a high population density."
To what extent do you agree with **this** statement? [10]

How do I approach these questions?

a) **i)** A calculation is required—the 1960 value is approximately 300 ppm and the 2015 value is approximately 390 ppm. A value between 80 and 100 ppm would be accepted.

ii) This requires manipulation of the temperature anomalies—from between 0.0–0.1°C in 1960 to just under 0.6°C in 2015, so approximately 0.6°C (0.5–0.6°C accepted).

b) This requires a labelled diagram that explains how the greenhouse effect works.

c) Part (i) asks you to suggest reasons. You do not necessarily need to know the exact reasons, but you should be able to come up with some logical ideas, for example, about spatial scales, temporal scales, the role of feedback, the complexity of the issue.

Part (ii) asks you to outline reasons. You should give a brief explanation of how climate change can be caused by natural processes, for example, volcanic activity, dust storms, variations in solar output and so on.

Essay

As the command term is **to what extent**, your answer should provide supporting arguments and counterarguments for the statement given in the question. Essay questions in papers 2 and 3 are also synoptic, which means you will need information from across different units to answer the question. For example, you might want to draw on your knowledge

of densely populated areas near coastlines (unit 1) to support the argument. However, you could counter the argument by describing how climate change impacts will also depend on latitude, and by discussing non-human impacts of climate change (unit 2).

SAMPLE STUDENT ANSWER

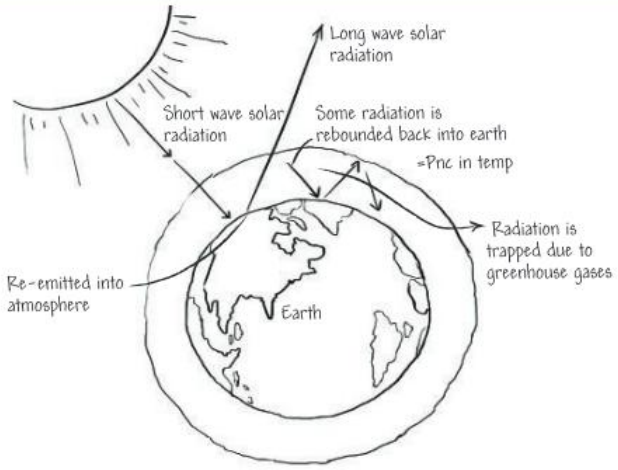
a) i) 300 ppm to 395 ppm, so an increase of 95 ppm of CO_2

Mark 1/1

ii) 0.6°C

Mark 1/1

b)



Marks gained for references to "short-wave solar radiation"; "radiation trapped due to greenhouse gases"; "long-wave radiation"; and "re-emitted into atmosphere".

Marks 4/4

c) i) Certain things influence the global climate such as natural disasters, for example volcanoes. It is difficult to predict how much the climate will change until after the event has happened. For example the Iceland volcano reduced solar radiation into the Earth, making the climate cooler.

▼ More detail needed—data? By how much cooler?

Another reason why predictions of climate change can vary is due to the fact that lots of things influence the climate of an area such as ocean circulation and air pressure, and these are constantly changing and so it is hard to predict future climate conditions accurately.

▼ Ocean circulation and air pressure not developed enough to explain how they affect global climate change

One factor and poor choice of support material—it had very limited impact on global climate. The eruption of Mt Pinatubo would have been better as support.

Mark 1/2

ii) Solar flaring is a natural cause of climate change which involves an increase in radiation received from the Sun, therefore changing the climate. Sun spots are the opposite of solar flaring which is when dark patches appear on the surface of the Sun.

Only one natural cause explained. Sun spots not developed enough.

Mark 1/2

Essay

"Climate change impacts will be greatest for places with a high population density." **To what extent** do you agree with this statement?

▲ Valid point

▲ Good exemplification of a number of factors influencing the impacts of global climate change

▲ Summary point

▲ Valid point and example

▲ Good development of point

▲ Impacts of global climate change on a rich country

▲ Good development—changes from a national scale to global megacities

▲ Valid point—the ability to cope (afford) climate change adaptation schemes

Climate change is one of the most important environmental issues of our age. However, its impacts are not evenly spread around the world. Its impacts vary with population density, relief (height above sea-level), proximity to the oceans (coastal locations) and level of wealth (poverty – being able to plan for climate change) as well as demographic factors e.g. age, health, number of dependents. It is a complex issue.

Climate change could potentially have a huge impact on low-lying countries, such as Bangladesh. For example, a 1-metre rise in sea level would flood over 10% of the country and affect 9% of the population. Rising sea levels in the UK's coastal waters would affect London and the South East, and the Severn Estuary and the Mersey Estuary. These areas contain many large and important cities. Globally, there are many sites that are vulnerable to climate change e.g. New York (which was affected by Superstorm Sandy in 2012), Shanghai (which is built on land less than 5m above sea level, and Tokyo, where much of the city is built on land reclaimed from the sea. However, although these cities have the potential to be affected, they also have the resources to adapt to climate change. London has the Thames Barrier to protect it against tidal flooding and New York is raising its sea walls and building a new barrier to deal with storm surges.

Not everywhere is so lucky. Small islands e.g. Kiribati, are vulnerable to rising sea level but do not have the resources to construct sea defences of a sufficient size and strength.

▲ Start of counterargument

Populations living in slums low-lying cities are particularly vulnerable. In Jakarta, about 40% of the city is below sea level, and the poorest live close to river banks, canals and drainage areas, making them especially vulnerable to flooding.

▲ Valid point and support

▲ Valid point—vulnerability of slum populations

In addition to flooding, they are vulnerable to freshwater contamination (by seawater) and the spread of diseases such as malaria and dengue fever.

▲ Good detail

▲ Good detail—range of hazards

However, the impact of climate change varies spatially. The largest temperature rises since 2000 have been in the Arctic, at over 10°C. This has had a major impact on the ice cover, animal migrations, forest fires etc. but relatively little impact on humans, as the region generally has a low population density.

▲ Another counterargument

▲ Valid point

▲ Valid point— impacts on the natural environment

Overall, it is not true to say that climate change will be greatest in areas of high population density. In some cases it may be so, especially in areas with a lack of resources to cope with the impacts of climate change, such as in the slums of Jakarta, but other impacts may be greater on the natural environment in areas of low population density, such as in the Arctic.

▲ Conclusion summarises argument and shows that it varies spatially (places) and due to wealth (power)

Good account—focused. Lots of valid support. Covers both sides of the argument, and has a conclusion that shows variations in place and power.

Marks 9/10