Evidence for climate change from the beginning of the Quaternary period to the present day

Ice Cores	• As ice forms, tiny bubbles of air are trapped in the ice. Each bubble is a tiny sample of air from the past; Scientists can measure how old they are from the depth they come from in the ice. • The trapped air contains a record of the carbon dioxide and methane levels at the time. This then gives an indication of what the temperature was like – the more CO_2 the warmer the temperatures were. • By comparing these readings from a large number of ice cores we can have a high degree of confidence in these results. • Scientists in Cambridge have found clear evidence of a rapid increase in temperature in recent decades.
Melting Ice	• The world's ice sheets are decreasing in size. • NASA data show that since 2002, the volume of ice lost in Antarctica is 134 billion tonnes per year, and 287 billion tonnes per year in Greenland. • Over the last 30 years, the Arctic ice has thinned to around half its earlier thickness. • There are fears that the Arctic could become ice-free by 2100.
Rising Sea Level	• Sea levels have risen by 19 centimetres since 1900 and are expected to continue to rise. • There are two reasons why sea levels have risen: 1. When temperatures rise and freshwater ice melts, more water flows to the seas from glaciers and ice caps 2. When ocean water warms it expands in volume – this is called thermal expansion
Glacial Retreat	• Photographs of glaciers taken in the Alps and other high mountain ranges since the mid-1800s highlight changes in the Earth's climate. • Glaciers throughout the world are shrinking and retreating. • It is estimated that some may disappear completely by 2035. • Glaciers in Iceland are retreating at up to 50 metres a year.
Direct Instrument Readings	• Direct measurements of temperature using thermometers show a clear warming trend. • Measurements show that, since the 1970s, there has been a rapid global temperature increase of around 0.55°C. • The warmest years on record have occurred in the last two decades with 2005 and 2010 only being beaten by the temperatures in 2014 when the average land and ocean temperatures were 0.69°C above the long-term average.
Increase in Extreme Weather Events	• No single extreme weather event can be blamed on climate change. However, scientists believe that a trend over many years could be linked to a warming world. • More energy in the atmosphere could lead to more intense storms. • The atmospheric circulation may be affected, bringing floods to normally dry regions and heatwaves to normally cooler areas. • In 2011 the IPCC concluded that extreme weather would become more common as global warming heats the planet.

Natural Causes of Climate Change

Orbital Changes

The Earth's orbit has 3 distinct cycles, known as Milankovitch cycles:

1. The Earth's orbit is sometimes circular, and sometimes more of an oval. A complete cycle from circular to oval and back to circular again occurs every 100,000 years. The cycle coincides closely with the alternating cold and warm periods in the Quaternary period.
2. The Earth's axis tilts. Sometimes it is more upright, and sometimes more on its side, moving back and forth between two extremes every 41,000 years.
3. The Earth's axis wobbles, like a spinning top about to fall over. A complete wobble cycle takes about 26,000 years.

These three orbital changes alter the amount of the Sun's energy that the Earth receives.

Volcanic Activity

Violent volcanic eruptions produce ash and sulphur dioxide gas. If the ash and gas rise high enough, they will be spread around the Earth by high level winds. The blanket of ash and gas will stop some sunlight reaching the Earth's surface. Instead, the sunlight is reflected off the ash and gas, back into space. This cools the planet and lowers the average temperature.

In 1991, Mount Pinatubo in the Philippines erupted. This was enough to reduce global sunlight by 10%, cooling the planet by 0.5°C for about a year.

Solar Output

The Sun's output (amount of energy produced) is not constant. It depends on the presence of sunspots. Sunspots are dark patches on the surface of the Sun.

The number of sunspots increases from a minimum to a maximum and then back to a minimum over a period of about 11 years. This 11 year period is called the sunspot cycle.

When sunspot activity is at a maximum the Sun gives off more heat. Large explosions occur on the surface of the Sun resulting in solar flares. This results in more solar energy being fired out from the Sun towards Earth.

When sunspot activity is at a minimum the solar output is reduced. This can lead to lower temperatures on Earth.

For example, very few sunspots were observed between the years 1645 and 1715. This coincided with the coldest period during the 'Little Ice Age' when Europe experienced a much colder climate with severe winters.

Human Causes of Climate Change

Use of Fossil Fuels

When fossil fuels (coal, oil and natural gas) are burned - by industry, in power stations and by vehicles and planes – gases enter the atmosphere. Carbon dioxide (CO_2), in particular, is given off when fossil fuels are burned.

Fossil fuels account for the majority of global greenhouse gas emissions – over 50%. Although these gases have always been present in the world's atmosphere, their concentration is gradually increasing as more and more fossil fuels are burned. Scientists believe that the build-up of so-called greenhouse gases in the atmosphere acts like a blanket or greenhouse around the planet; heat is trapped inside the Earth's atmosphere. This is the greenhouse effect, and the resulting increase in global temperatures is called global warming.

As the world's population grows and wealth increases, people are demanding more and more energy, which increases the use of fossil fuels and the release of carbon dioxide.

Agriculture

Agriculture produces large volumes of methane and contributes to approximately 20% of global greenhouse gas emissions. For example:

- cattle (cows) produce methane during digestion;
- rice farming - microbes produce methane as they decay organic matter under the water of flooded rice paddy fields.

As the world's population increases, more food is required, especially in areas such as Asia where rice is the staple diet. This means the demand for meat and rice is higher and methane levels are rising.

If current population rates continue, it is inevitable that large-scale agriculture's contribution to climate change will continue to grow.

Deforestation

Deforestation is the clearing of forests on a huge scale. If deforestation continues at the current rate, the world's forests could disappear completely within a hundred years. There are several reasons why forests are cut down:

- logging for wood and paper products;
- making room for the expansion of urban areas;
- clearing land for agriculture (space for crops and livestock);
- building roads to access remote areas.

During the process of photosynthesis, trees absorb carbon dioxide, which reduces the amount of carbon dioxide in the atmosphere. Deforestation leaves fewer trees to absorb carbon dioxide. Therefore the enhanced greenhouse gases contribute to rapid climate change.

In addition, when trees are burnt to clear an area, such as with slash and burn, the carbon dioxide that has been stored is also released, which again contributes to climate change.

Managing the Impact of Climate Change

There are 2 ways of managing climate change:

1. **Adaptation** is when people adapt and respond to the impacts of climate change.
2. **Mitigation** is when people try to reduce the causes of climate change.

Mitigation 1 - Alternative energy production



Instead of burning fossil fuels, which release CO_2, we could use RENEWABLE forms of energy. The UK aims to produce 15% of its energy from renewable sources by 2020.

Type	Description	Advantages	Disadvantages
Wind	Modern windmills, called wind turbines, turn wind energy into electricity. If the turbines are in a group it's called a wind farm.	Wind is a renewable energy source, which **will never run out**. The **price of wind energy is stable**; it doesn't go up and down like the price of coal or oil. The **UK gets lots of wind** annually Wind turbines **do not produce CO_2**	Some people say they are **noisy** and **look unpleasant** **Unpredictable** – the amount of energy made varies with wind strength **Take up large amounts of land** (7ha for every megawatt of energy made)
Solar Power	Electricity is generated by solar power in two ways: • Using the sun's heat to boil water and produce steam which drives turbines • By using photovoltaic (PV) cells	Solar panels **give off no pollution** the only pollution produced as a result of solar panels is the manufacturing, transportation and installation. Solar energy produces electricity very **quietly** & can be used globally. New technologies like batteries allow capture of energy during the day for use at night.	Solar panels **cost a lot**. Currently, prices of highly efficient solar cells can be above £1000, and most households may need more than one. Solar energy is **only able to generate electricity during daylight** hours. In areas such as the UK sunshine is not very reliable.
Tidal Power	Tidal barrages (dams) are built. Water turns a turbine that generates electricity	**Reliable and predictable** as tides are regular. Tidal barrages **do not produce CO_2** and a single barrage can provide the same energy as five nuclear power stations.	Construction **costs are extremely high**. May **destroy the habitat** of migrating birds and turbines can **kill aquatic animals**.

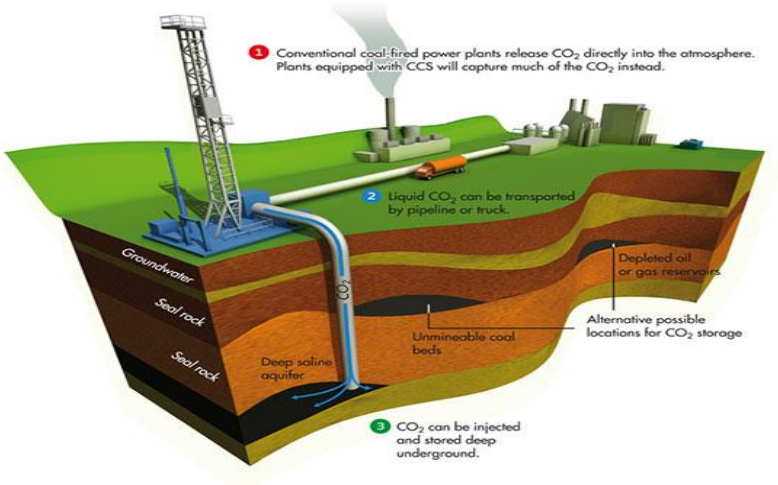
Mitigation 2 - Carbon capture

Carbon capture is the trapping of the carbon dioxide released when we burn fossil fuels.

1. • The CO_2 released by power stations is captured before it can enter the atmosphere
2. • The CO_2 is turned into a liquid and tranported by pipeline or truck to the storage site
3. • The CO_2 is injected into the ground and stored in deep underground reservoirs e.g. old coal seams or old unused oil and gas wells

Benefits: It is possible to capture up to 90% of the CO_2 that would otherwise enter the atmosphere. Carbon capture would allow us to reduce our carbon emissions whilst still using cheap fossil fuels to produce our electricity.

Negatives: Not all CO_2 can be captured. It is also very expensive to "capture" it.

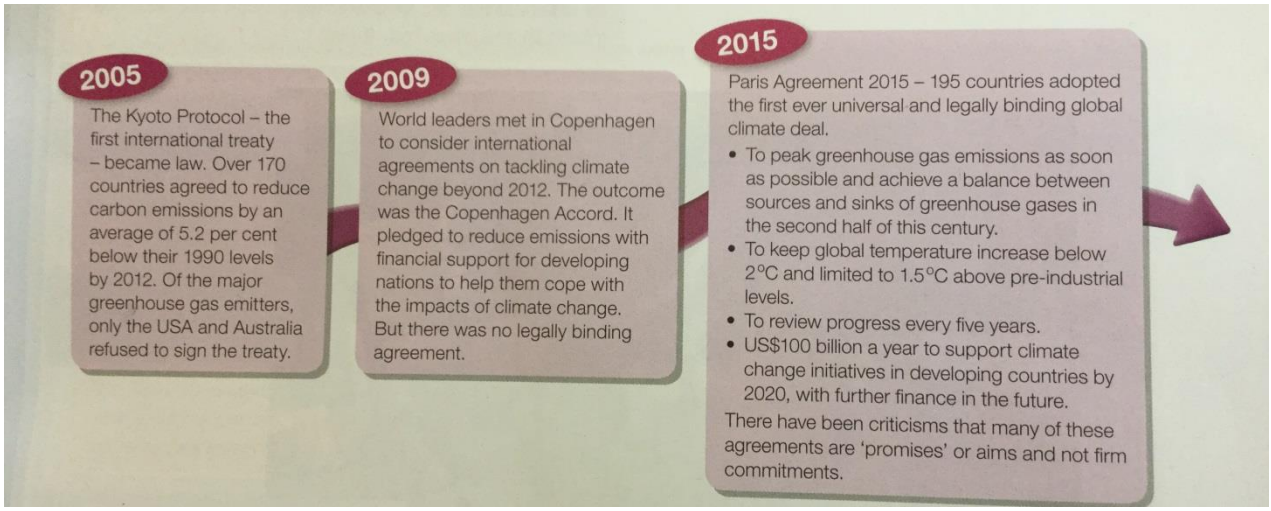


Mitigation 3 - Planting trees

A practical way to mitigate climate change is to plant more trees in order to take more carbon out of the atmosphere. This is known as afforestation.

Trees act as carbon sinks, removing Co_2 from the atmosphere by the process of photosynthesis. They also release moisture into the atmosphere. This has a cooling effect by producing more cloud, reducing incoming solar radiation.

Mitigation 4 - International agreements



Adaptation 1 - Change in agricultural systems

Agriculture (farming) will need to adjust to climate change. In particular, it will need to adapt to changing temperature and rainfall patterns and an increase in extreme weather events such as heatwaves, droughts and flooding.

To adjust farmers and governments will need to consider:

- Changing the crops and varieties grown, e.g. introducing drought-resistant crops such as wheat variety Seri M82 with a deeper root system to help access more water.
- Changing the time of year crops are planted.
- Educating farmers on how to use technology (e.g. dams and reservoirs) to "harvest" water in areas where rainfall decreases.
- Educating farmers on how to conserve soil moisture in areas where rainfall decreases.
- Planting shade trees to protect seedlings from strong sunshine in areas where temperature increases.
- Moving crop production to new, more suitable, locations.
- Draining water to prevent water logging, erosion, and nutrient leaching where rainfall increases.
- Changing livestock breeding practices and shifting grazing patterns.
- Improving pest, disease, and weed control as these might change location with climate change.

The cost of adapting to climate change will be more difficult for poorer subsistence farmers.

Importance: If we are to feed the world, the United Nation's Food and Agriculture Organisation says that agriculture will need to be 'climate smart'.

Adaptation 2- Managing water supply

Dry areas are predicted to get drier, leading to more water shortages.

There are two ways water can be managed:

1. Reducing Demand – In London, a Water Strategy is being used to reduce water demand. By 2030, all London homes are to be offered a free package of water-saving devices such as tap aerators and shower timers.
2. Increasing Supply – Thames Water opened a desalination plant in London in 2010 to increase water supply. Water is taken from the River Thames at low tide (when it is least salty) and turned into drinking water for 400,000 homes.

   An artificial glacier project is being used in the Himalayas to supply water to villages in Ladakh, India. Water is collected in winter and frozen as an artificial glacier. When the 'glacier' melts in spring it provides water for the local villages.

Adaptation 3 - Reducing risk from rising sea levels

Sea levels are predicted to rise by up to 82cm by 2100, which would flood many islands and coastal areas.

Managing rising sea levels in the Maldives:

Background Information: The Maldives are a group of islands in the Indian Ocean. The highest point on the islands is just 2.4 metres above sea level. Some climate models suggest the islands may be uninhabitable by 2030 and completely submerged by 2070.

Adaptations – How can the Maldives manage sea level rise?

- A 3 meter sea wall is being constructed around the capital Male with sandbags used elsewhere.
- Houses are being built that are raised off the ground on stilts
- Coastal mangrove forests are being replanted – the tangled roots of the trees trap sediment and protect the coastline from storm waves.
- The entire population could be relocated to Sri Lanka or India
- Artificial islands could be constructed to relocate people to.

Managing rising sea levels in London:

London is currently well protected against sea levels. The Thames Barrier was built in 1982 to stop tidal surges (sea water) entering central London. It has been closed over 100 times since it was built, preventing central London from flooding. As sea levels rise, it is likely that the Thames Barrier will need to be closed more frequently.