

Climate change

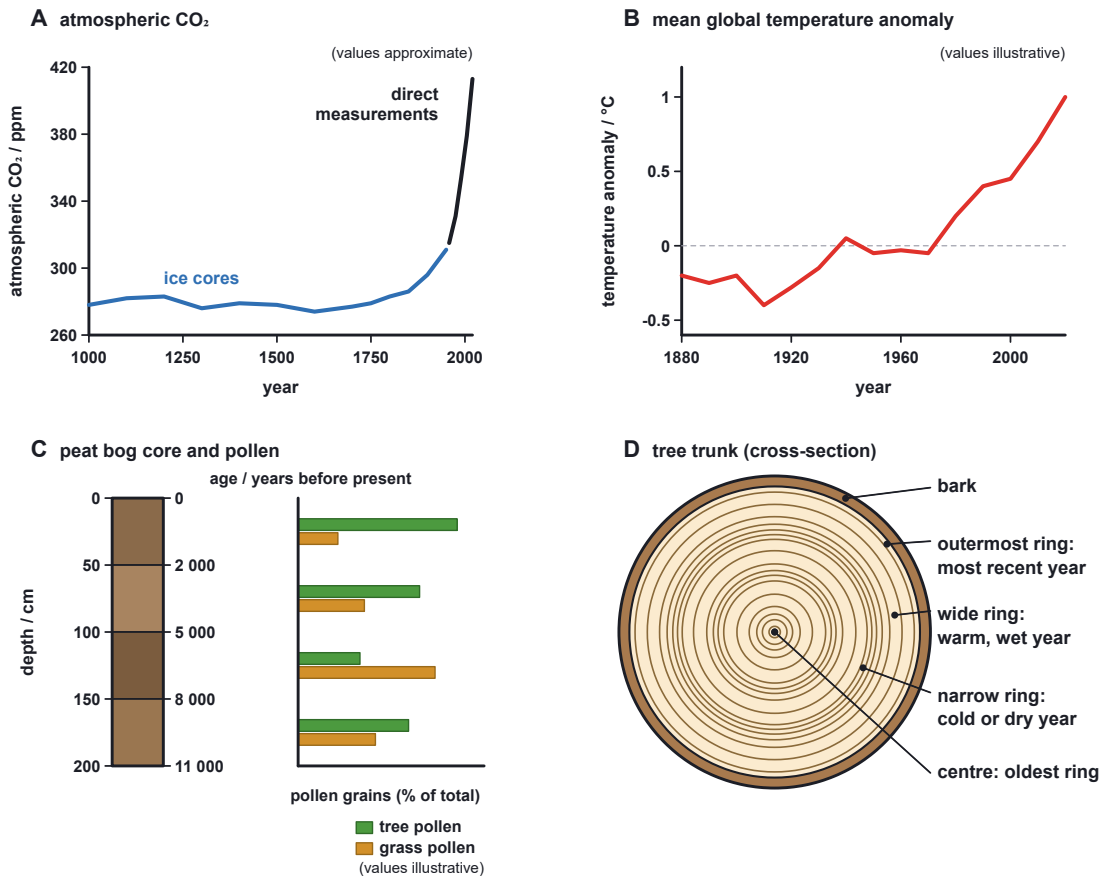
Revision notes · Evidence for and causes of climate change, the carbon cycle, models, effects on organisms, and the conflict between human needs and conservation.

For Pearson Edexcel International AS Biology XBI11 and International A Level Biology YBI11. **A Level only** is IA2 content (Units 4 to 6), not needed for the International AS.

Climate change **Spec 5.16–5.20, 5.25–5.26** **A Level only**

Evidence for climate change **Spec 5.16**

Evidence for climate change			
Evidence	What is measured	What it shows	Limitations
Carbon dioxide records	Direct measurement of atmospheric CO ₂ (for example continuous measurements since the 1950s); CO ₂ in air bubbles trapped in ice cores for earlier times	A rise in atmospheric CO ₂ concentration, with a steep rise since the industrial revolution; ice cores cover hundreds of thousands of years	Ice-core values are indirect and become less precise further back; local sources can affect some records
Temperature records	Thermometer readings from weather stations, ships and satellites; earlier temperatures estimated from other evidence	Mean global temperature has risen, especially since about 1950	Coverage of early records is patchy; local effects such as urban heating; different measurement methods
Pollen in peat bogs	Pollen grains preserved in the acidic, anaerobic (waterlogged) layers of peat. Layers are dated (for example by radiocarbon dating) and the pollen is identified and counted	The species of plants present at different times. Each species has a climate it tolerates, so the pollen record shows what the climate was like	Pollen can be blown from elsewhere; plants respond to other factors, such as soil and human activity; identification to species level can be hard
Dendrochronology (tree rings)	Counting and measuring the width of annual rings in trees. Overlapping patterns of ring widths from living and dead trees extend the record	Wide rings suggest warm, wet years with good growth; narrow rings suggest cold or dry years. Gives precise dates for past conditions	Growth is also affected by disease, competition and nutrients; only tells about local conditions; limited to areas where trees grow



Four types of evidence: ice cores, temperature records, pollen in peat and tree rings.

Correlation and causation

Data from different sources can be compared on one graph. A **correlation** exists where two variables change together, for example atmospheric CO₂ concentration and mean global temperature. A correlation alone does not show that one causes the other: both could be caused by a third factor. A **causal relationship** is supported when there is also a known mechanism (here the greenhouse effect), the correlation is seen repeatedly in many independent data sets, and the cause comes before the effect.

Exam tip: In data questions say 'there is a positive correlation between ...' and then discuss whether it shows cause. Use evidence such as a known mechanism and data from several independent sources to support a causal link.

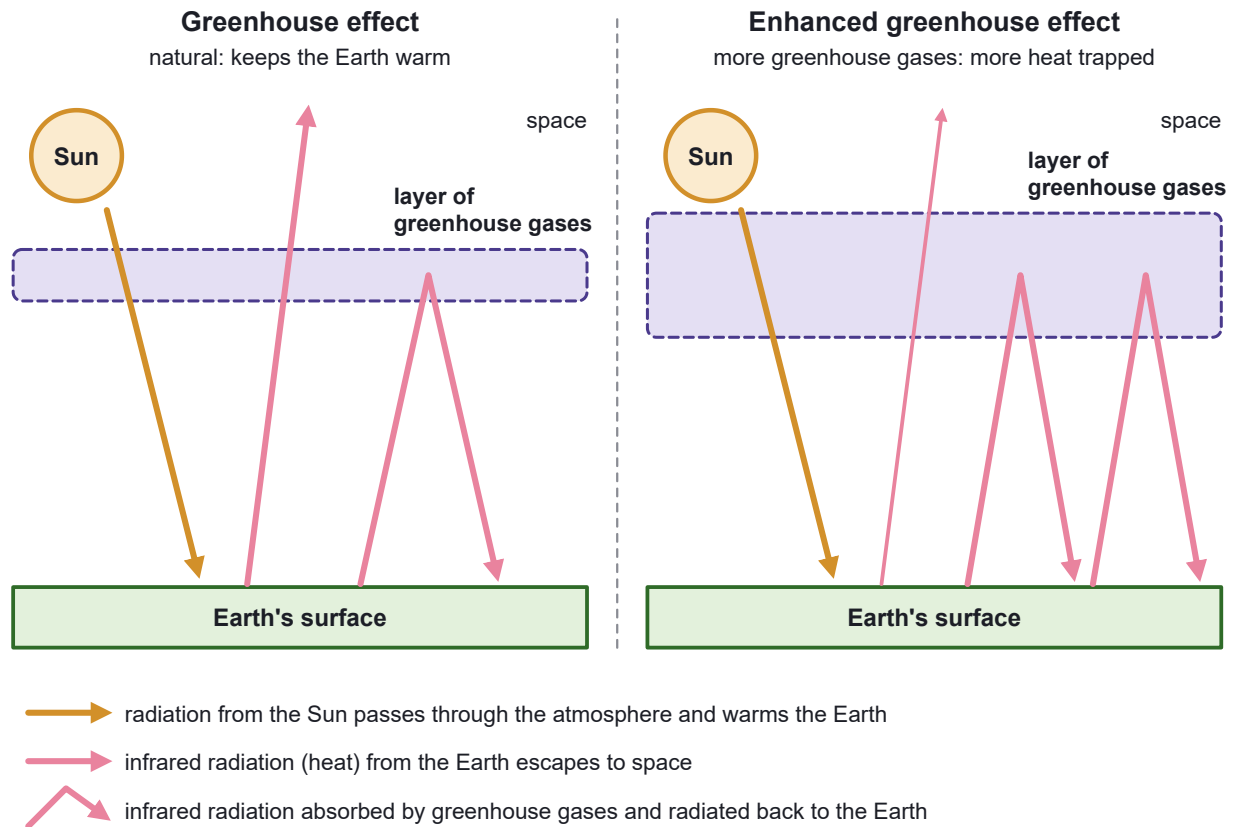
Causes of anthropogenic climate change and the greenhouse effect Spec 5.17

The greenhouse effect

1. Short-wavelength radiation (visible light) from the Sun passes through the atmosphere. Some is reflected, and the rest is absorbed by Earth's surface and warms it.
2. The warmed surface emits radiation at longer wavelengths, as infra-red radiation (heat).
3. **Greenhouse gases** in the atmosphere absorb some of this infra-red radiation and re-radiate it in all directions, including back towards Earth's surface.
4. This traps heat, and keeps the lower atmosphere warmer than it would be otherwise. This natural process keeps average temperatures suitable for life.

The main greenhouse gases are carbon dioxide, methane, water vapour, nitrous oxide and CFCs. They differ in how long they stay in the atmosphere and in how effective they are at absorbing infra-red

radiation: for each molecule, methane is more effective than carbon dioxide, but carbon dioxide is far more abundant.



Greenhouse gases: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), CFCs and water vapour

The greenhouse effect and the **enhanced greenhouse effect**: more greenhouse gases trap more infrared radiation.

Anthropogenic causes

Anthropogenic means caused by humans. Since the industrial revolution, human activities have increased the concentrations of greenhouse gases, an **enhanced greenhouse effect** that has led to global warming.

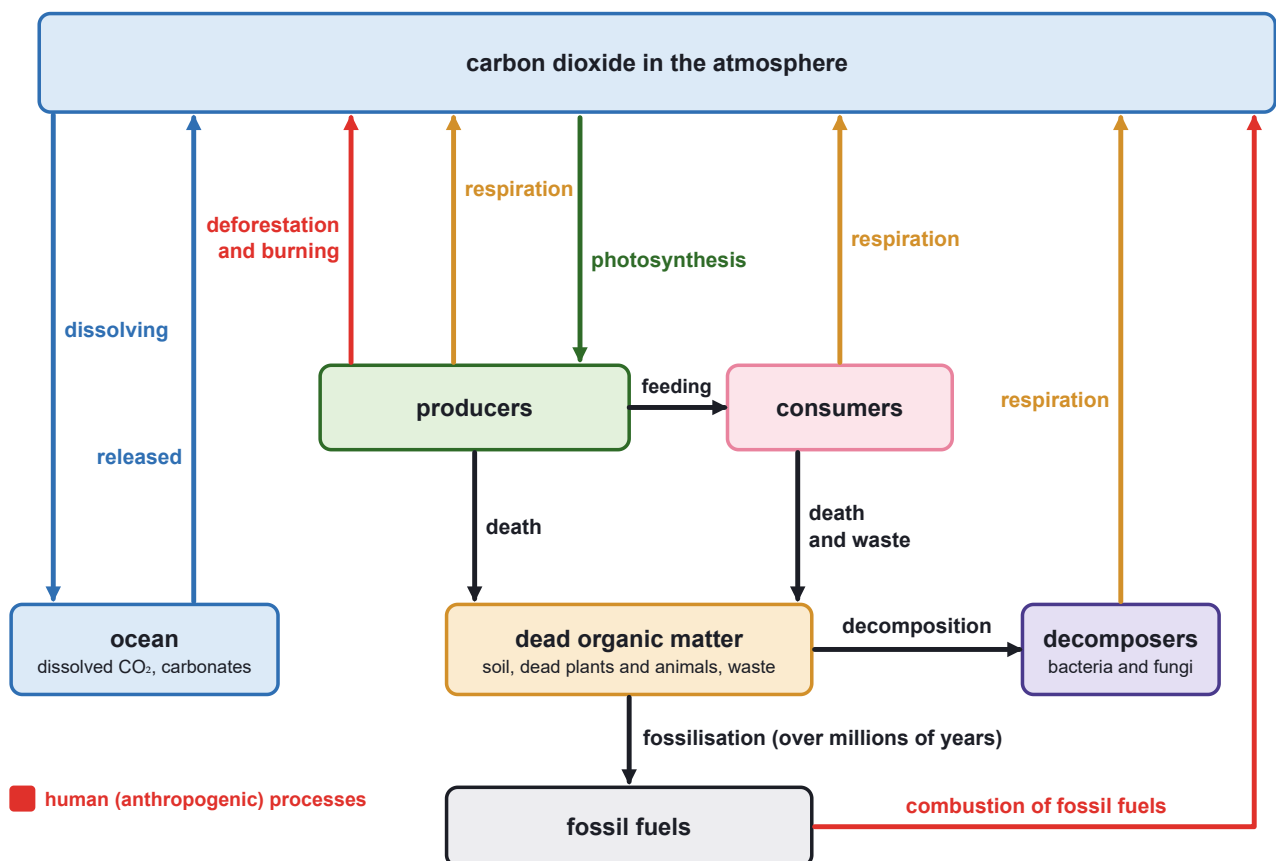
Human activities and greenhouse gases		
Human activity	Greenhouse gas affected	Effect
Burning fossil fuels (coal, oil, gas) in power stations, transport and industry	Carbon dioxide	Releases carbon that has been locked up in fossil fuels for millions of years
Deforestation, especially by burning	Carbon dioxide	Burning and decay release stored carbon; fewer trees remove less carbon dioxide by photosynthesis
Cattle and sheep farming; rice paddies; landfill	Methane	Ruminants release methane from digestion; waterlogged soils and rotting waste give anaerobic decomposition
Use of nitrogen fertilisers	Nitrous oxide	Released by denitrifying bacteria in the soil
Use of refrigerants and aerosol propellants (CFCs)	CFCs	Absorb infra-red radiation strongly (CFCs also damage the ozone layer)

Common mistake: The greenhouse effect itself is natural and essential. It is the enhanced greenhouse effect, caused by extra greenhouse gases, that leads to climate change. The ozone layer is a different issue.

The carbon cycle and reducing atmospheric carbon dioxide Spec 5.18

The **carbon cycle** describes how carbon moves between the atmosphere, oceans, living organisms, soil and rocks. Carbon is held in **sinks** such as plants, soil, oceans and fossil fuels, and moves between them in the following processes.

Carbon cycle processes	
Process	Effect on atmospheric CO ₂
Photosynthesis (plants, algae, cyanobacteria)	Removes CO ₂ and stores carbon in organic molecules
Respiration (all organisms)	Returns CO ₂ to the atmosphere
Feeding	Transfers carbon compounds along food chains
Decomposition by bacteria and fungi	Returns CO ₂ to the atmosphere (and methane in anaerobic conditions)
Fossilisation (when decomposition is incomplete)	Locks carbon in peat, coal, oil and gas for millions of years
Combustion (fossil fuels and biomass)	Rapidly returns stored carbon as CO ₂
Dissolving in oceans; formation of carbonates	Removes CO ₂ from the atmosphere and stores it in the ocean



The **carbon cycle**, with human (anthropogenic) processes in red.

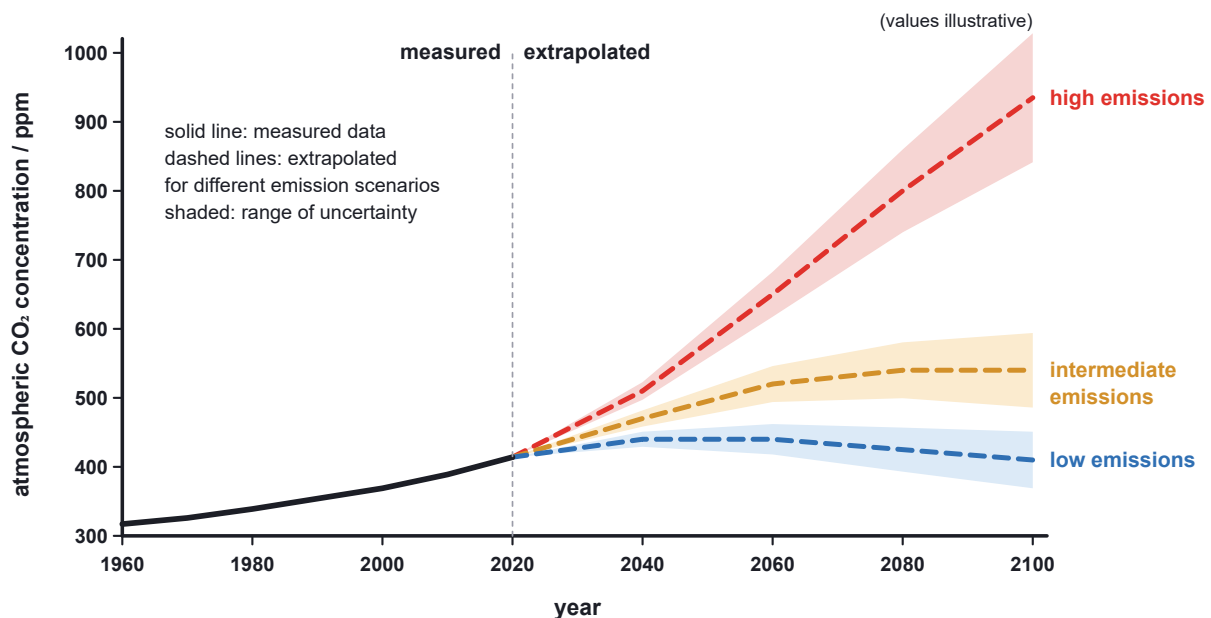
Applying knowledge of the cycle to reduce atmospheric CO₂

- **Afforestation and reforestation**: planting trees increases photosynthesis, so more CO₂ is removed from the atmosphere and held in wood. It works only while the trees grow, and carbon is released again if the wood is burnt or the forest destroyed.
- **Protecting existing forests, peat bogs and wetlands**: these are large carbon sinks. Draining peat or burning forests releases stored carbon. Preventing deforestation keeps this carbon locked up.
- Reducing the combustion of fossil fuels: using renewable energy (wind, solar, hydroelectric) and energy efficiency reduces the transfer of carbon from the fossil store to the atmosphere.
- Using **biofuels** in place of fossil fuels: the carbon dioxide released on burning was recently absorbed by the plants, so the process may be close to carbon neutral (see 5.26 for conflicts).
- Reducing decomposition and respiration of soils and returning organic matter to the soil, for example by minimal tillage, keeps carbon in the soil.
- Carbon capture and storage: carbon dioxide from power stations is collected and stored underground. It does not change the cycle itself but reduces the flow to the atmosphere.

Exam tip: Always link a method to a stage of the cycle: 'planting trees increases photosynthesis, which removes CO₂ from the atmosphere' scores; 'trees absorb CO₂' on its own may not.

Predicting climate change: extrapolation and models Spec 5.19

Extrapolation means extending a line or curve beyond the measured data to predict what might happen in the future. Predictions are used in **models** of future climate change, which use data on greenhouse gas concentrations, temperature, ice cover and ocean currents to estimate how much warming might occur under different assumptions (for example scenarios of high or low emissions).



Extrapolating measured CO₂ data to 2100 under different emission scenarios (values illustrative).

Limitations of models

- The climate is a **complex system** with many interacting factors (oceans, clouds, ice, vegetation, volcanic activity), and it is not possible to include them all accurately.
- Models contain **feedback loops**, which are hard to represent. Positive feedback increases the change: for example, melting ice exposes darker surfaces that absorb more heat; warming thaws

permafrost and releases methane. Negative feedback reduces change: for example, more CO₂ may increase plant growth.

- Data may be incomplete or unreliable, especially for the past and for remote areas, and small errors in the data are amplified in the predictions.
- Extrapolation assumes that the trend continues as it has done, which may not be true. Predictions depend on assumptions about future human behaviour, such as emissions and population growth, which cannot be known.
- Different models give different predictions, so there is uncertainty. A model can be tested by checking whether it reproduces known past climates.

Exam tip: A 'limitation' needs a reason. Write 'the model may not predict accurately because it cannot include all the variables, such as feedback from melting ice' rather than just 'models are not accurate'.

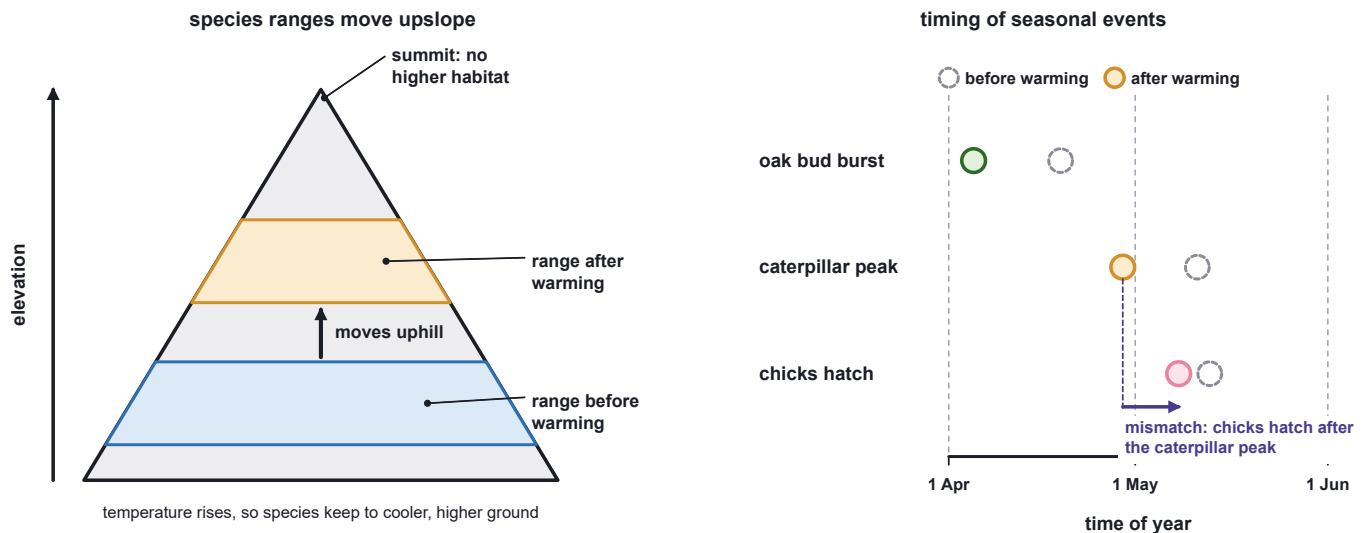
Effects of climate change on plants and animals Spec 5.20

Distribution of species

Each species survives within a range of abiotic conditions. As temperatures and rainfall change, the area that meets these conditions moves. Species move **towards the poles** or **to higher altitude** if they can, or their range contracts if they cannot. Examples include warm-adapted species such as some insects and plants spreading into new areas, and cold-adapted species in the Arctic and on mountain tops losing habitat. Changes in rainfall alter water availability, so drought-tolerant species can replace others, and species may become isolated when habitats change.

Development and life cycles

- Higher temperatures speed up enzyme-controlled reactions in ectotherms, so some insects complete their life cycle faster and may produce more generations per year.
- Seasonal events occur earlier: leaves open, plants flower, insects emerge and eggs hatch earlier in spring, and some animals migrate at different times or stop migrating.
- Species that depend on one another may respond differently, so timing may no longer match. For example, if caterpillars emerge earlier but the birds that feed their chicks on them lay at the same time as before, there is less food when chicks hatch and fewer survive.
- Changes in rainfall affect the timing of germination and breeding in species that depend on wet or dry seasons.
- Changes in the length and warmth of the growing season affect plant growth, seed production and crop yields.



Climate change shifts where species live and **phenology**, and unequal shifts cause a mismatch.

Exam tip: Always say what has changed (for example temperature or rainfall) and then how it affects the organism (for example faster development or a shifted range). Use named examples if you can, but the explanation matters more than the example.

Evaluating scientific conclusions on controversial issues Spec 5.25

Climate change is a controversial issue because the actions needed have economic, political and social consequences. The scientific evidence may be the same, but the conclusions drawn can depend on **who is reaching them** and why.

- **Vested interest**: an organisation that profits from fossil fuels may emphasise uncertainty, while an organisation that campaigns for the environment may emphasise the worst predictions.
- **Funding**: who paid for the research may influence which questions are asked and how results are reported.
- **Selection of data**: a conclusion may use only the data that support it (a narrow time period, or one region), or compare different measurements.
- **Qualifications and expertise**: a conclusion from experts in climate science is more reliable than one from people without relevant expertise.
- **Peer review**: research that has been checked by other independent scientists before publication is more reliable than claims that have not.
- **Media and politics**: reports in the media may simplify, exaggerate or present a balanced debate as if scientists were equally divided.
- **Different assumptions**: governments and countries weigh economic costs, development and fairness differently, so they may disagree on actions even when they agree on the science.

Exam tip: To evaluate a source, ask: who wrote it, who funded it, what evidence is used, is it from a peer-reviewed source, is the data selected, and is the conclusion supported by the data? Then give a judgement.

Reforestation, sustainable resources and biofuels Spec 5.26

There is a conflict between human needs (energy, wood, farmland, food) and **conservation** of ecosystems and biodiversity. **Sustainable** use meets present needs without reducing the ability of future generations to meet theirs.

Managing the conflict between human needs and conservation

Approach	How it helps	Possible problems
Reforestation (replanting trees, for example after logging) and sustainable forestry (felling only as many trees as are replaced, replanting, selective felling, coppicing)	Timber is still available; trees remove CO ₂ by photosynthesis, store carbon, protect soil and provide habitats	Planting a single species (monoculture) supports less biodiversity than natural forest; young forests store less carbon than mature forest; needs time and land
Biofuels: fuels made from recently grown biomass, such as ethanol from sugar cane or maize and biodiesel from oil crops	The CO ₂ released on burning was taken in by the crop, so they may be close to carbon neutral; reduce use of fossil fuels	Growing crops needs land, which may be taken from forest or food crops; fertilisers, machinery and processing use energy and release greenhouse gases; monocultures reduce biodiversity
Other sustainable resources (renewable energy, sustainably sourced timber and fish with quotas)	Reduce the use of finite resources and the release of greenhouse gases	Cost, land use, and impact on habitats must be balanced

The best management usually involves compromise: for example, using waste plant material or non-food crops grown on poor land for biofuels, rather than clearing rainforest to grow oil palm, and combining reforestation with the protection of mature forest.

Exam tip: A good answer to an evaluation question gives one benefit and one drawback, and then a judgement about how well the conflict has been managed.

Quick check

1. Name two sources of indirect evidence for past climates.
2. What is an anthropogenic cause of climate change?
3. Which processes in the carbon cycle remove CO₂ from the atmosphere?
4. State one limitation of climate models.
5. Why might the conclusions about climate change differ between organisations?

Quick check answers

Climate change

1. Pollen in peat bogs and tree rings (dendrochronology). Ice cores are also acceptable.
2. One caused by human activity, such as burning fossil fuels or deforestation.
3. Photosynthesis and dissolving in the oceans.
4. Climate is a complex system with feedback loops that cannot all be included accurately.
5. Vested interests, funding or selection of data can influence the conclusions.