Environmental Studies
FACT SHEET
www.curriculum-press.co.uk
Number 037

Greenhouse Effect & Kyoto Update

Greenhouse effect basics:
- Incoming radiation from the sun warms the Earth's surface
- The Earth's surface re-radiates energy back to space as infrared radiation
- Greenhouse gases trap/delay the release of this energy
- This is warming our lower atmosphere
- Humans are responsible for hugely increasing the concentration of greenhouse gases
- The most important greenhouse gases are:
  - Water Vapour
  - Carbon Dioxide (CO_2)
  - Methane (CH_4)
  - Nitrous Oxide (N_2O)
  - Hydrofluorocarbons (HFC's)
  - Perfluorocarbon (PFC's)
  - Sulphur hexafloride (SF_6)

- Although water vapour is the greenhouse gas with the greatest concentration in the atmosphere (1%), human effect on it is negligible and it isn't included in the Kyoto protocol - the international agreement to reduce global climate change.

- Warming of the troposphere (the lower part of the atmosphere) is likely to cause weather changes and sea level rises that could have serious effects on the way we live and on other animal and plant species.

- Most scientist now agree that:
  1. The atmosphere and oceans are getting warmer (atmospheric increase of 0.6°C since 1902)
  2. We are responsible for the above affect.

Table 1. Atmospheric Concentrations
(ppm = parts per mllion , ppt = parts per trillion)

Gas	Pre 1750	2003	Average annual change 1990-1999	Atmospheric Lifetime (Yr's)
CO_2	278 ppm	365 ppm	1.5	50-200
CH_4	0.7 ppm	1.7 ppm	0.008	12
N_2O	0.27 ppm	0.31 ppm	0.003	114
SF_6	0 ppt	40 ppt	0.2	3,200
$PFCH_4$	40 ppt	80 ppt	1.0	>50,000

The table shows:
- The concentration of the top 5 greenhouse gases is increasing.
- Some stay in the atmosphere – having a warming effect – for a **very** long time.
- So even if we stop the increase now, our past actions will be affecting us i.e. our children for decades.

However the table hides some important points…
- Most greenhouse gases have both natural sources and human sources
- Natural sources used to be balanced by natural ways of absorbing the gases (natural sinks).
- We are (i) increasing natural sources (ii) decreasing natural sinks (iii) increasing human sources.
- The overall effect is that emissions now exceed the amount that can be absorbed (Table 2, 3 & 4).

Table 2. Sources of Greenhouse gases

Gases	Human Sources	Natural Sources
CO_2	Fossil fuel burning, deforestation	Respiration Natural fires
CH_4	Leakage from extraction of fossil fuels, landfill, ruminants	Anaerobic decay of vegetation Termites
N_2O	Application of N fertilisers Fossil fuel burning Nylon manufacture Biomass burning	Bacterial breakdown of N compounds Photo-dissociation of N_2 and reaction with O_2 in atmosphere
PFC's	Aluminium smelting Semiconductor manufacture	Fluorite rocks
SF_6	Electrical insulation, magnesium smelting	Fluorite rocks

Table 3. Sinks of greenhouse gases

Gases	Sinks
CO_2	Ocean absorption, photosynthesis
CH_4	Troposphere reaction with OH^-, stratosphere reaction with OH^- and CL_2
N_2O	Acid deposition
PFC's	Photolysis and ion reactions in the mesosphere
SF_6	Photolysis and ion reactions in the mesosphere

Table 4. Nature and humans: Sources and absorption of greenhouse gases (mmt)

Gas	Natural source	Human source	Total source	Absorption (sinks)	Annual increase in atmosphere
CO_2	770,000	23,100	793,100	781,400	11,700
CH_4	239	359	598	576	22
N_2O	9.5	6.9	16.4	12.6	3.8

Who are the CO_2 polluters?

Table 5. The Top 10 CO_2 poluters (in 2000)

Country	Emissions (million metric tons)
USA	1528
China	761
Russian Federation	391
Japan	323
India	292
Germany	214
UK	154
Canada	118
Italy	116
Korea	115

- The USA is the planet's worst polluter – it has signed the Kyoto protocol but the US government hasn't agreed to abide by it.
- US per capita figures are also the highest in the world.

Typical Exam Questions will ask you to:
1. *Name the greenhouse gases, their sources and their sinks.*
2. *Outline the process of global warming*
3. *Describe the possible effects*
4. *Recall and interpret negative and positive feedback effects*
5. *Describe and evaluate ways of tackling global climate change*

Positive and negative feedbacks

Remember: a positive feedback mechanism (although it sounds like an encouraging response) is generally BAD! It accelerates any movement away from a stable point.

→ temp → ↑ rate of respiration → ↑ CO_2 → ↑ temp
increasing the temperature has caused things to happen which further increases temperature

Remember: A negative feedback mechanism is generally GOOD! It works against any movement away from a stable point and brings a system back into equilibrium.

→ temp → ↑ rate of rphotosynthesis → ↓ CO_2 → ↓ temp

BUT: the possible +ve and –ve feedbacks in the global climate are mind-bogglingly complex! Our best scientific models, painstakingly created by the world's best scientists, are pretty crude and the truth is we simply don't know what is going to happen as the earth warms up.

Typical Exam Question: What types of feedback are these?
1. *↑ temp → ↑ ice caps melt → ↓ albedo → ↑ temp*
2. *↑ temp → ↑ evaporation → ↑ clouds → ↑ trapping of reradiation → ↑ temp*
3. *↑ temp → ↑ rate of decomposition → ↑ CO_2 → ↑ rate of photosynthesis → ↓ CO_2*
   ↘ ↑ temp

Kyoto Protocol

- Countries which sign agree to reduce their greenhouse gas emissions
- Gases covered include CO_2, CH_4, N_2O, HFC's, PFC's, SF_6
- Signatories have to show 'demonstrable progress' by 2005
- Mechanisms that can be used include:

Emissions trading
- Starts at the end of 2005 and covers all EU countries
- Each country puts a 'cap' (an upper limit) – on CO_2 emissions from large industries
- But some industries/companies will not be able to stay within the cap e.g. in some industries, reducing CO_2 emissions might be extremely expensive. To make the reductions would cost so much that the company would be in danger of going out of business.
- They can buy emissions credits from a company that is well within it's own cap.

  e.g. Cap = 20Mt CO_2/yr
  Co. 1 gets its emissions down to 24 Mt CO_2/yr
  Co.2 gets its 16 Mt CO_2/yr
  Co. 1 buys 4 Mt of credits from Co. 2 (or pays a fine)

The scheme tries to ensure that reductions are made at the least cost.

Joint Implementation
Country A can help country B reduce it's emissions and claim some of the reduction as it's own

Joint fulfilment
EU countries can add up their total targets and re-allocate them so that countries that are going to find it difficult can be helped out by another country doing more

Clean development mechanism
Signatories can help any other country anywhere (even non-signatories) to reduce emissions and claim the reductions as their own.

The huge problem at the moment is in the US. It signed the protocol in 1998 but President Bush refused to put the agreement to the Senate. Without the Senate's agreement the US does not have to do anything. President Bush gave the following reason for refusing to put it to the Senate:

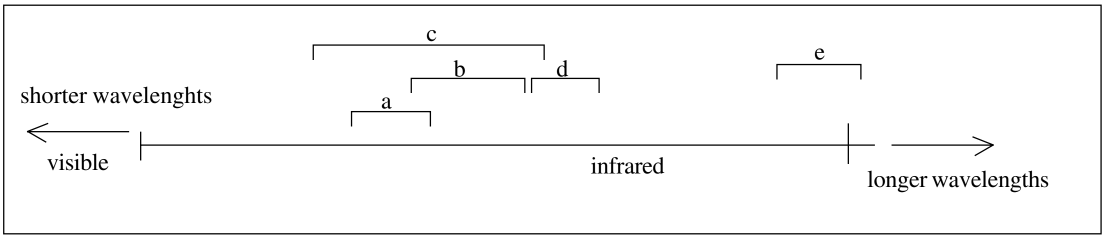
"It (the Protocol) exempts 80% of the world, including China and India… and would cause serious harm to the US."

Typical Exam Questions
Q. Why do you think China and India are excluded from the Protocol?
Q. How could it cause serious harm to the US?

Global Warming Potentials (GWP's)

Taking the science a bit further…….

- Different gases absorb different wavelengths
- Some wavelengths are absorbed by several greenhouse gases e.g. look at the diagram, which show the infrared part of the electromagnetic spectrum.
- Imagine five greenhouse gases, a, b, c, d and e
- The lines show which wavelengths each gas absorbs
- You can see that there is some overlap – gases a, b and c are all capable of absorbing some of the same wavelengths



So What?

- Well, a 1% increase in emissions of gas b might have little effect at trapping more heat – gases a and c are already absorbing these wavelengths
- BUT a 1% increse in gas e might have a huge warming effect – because no other gas is trapping these wavelengths.
- So it isn't just how much gas there is, it's what it's absorbing (and how long itn stays around)

This is why greenhouse gases such as SF_6 and PFC's are so worrying. Furthermore, we are still discovering 'new' greenhouse gases that 5 years ago no-one was mentioning. Trifluoromethyl sulphur pentafluoride (SF_5CF_3) is one such new greenhouse gas. It is created by the breakdown of SF_6 in high voltage equipment. It didn't exist until 1960 and now its concentration is just 0.12 ppt – but it has the greastest GWP of any known gas. It isn't included in any legislation or agreement.

Ther are several other gases and particles that contribute to global warming but are not included in the Kyoto protocol. These include tropospheric and stratospheric ozone and aerosols including sulphates and black soot. Other substances such as carbon monoxide , nitrogen oxides and volatile organic compounds (VOCs) act as indirect greenhouse gases. These are emitted during combustion of fossil fuels and biomass and influence climate indirectly by affecting the formation of ozone and methane, for example.

So which greenhouse gas is the most important?

Tricky Question!

As we have discussed, the ability of a greenhouse gas to affect global temperature depends on:

(i) it's ability to trap heat (which wavelengths it absorbs)
(ii) it's lifetime in the atmosphere.

We can compare the relative effect of different gases by calculating their global warming potential (GWP's). For reference CO_2 is given a GWP of 1.

Gas	GWP
CO_2	1
CH_4	11
N_2O	270
CFC-11	3400
CFC-12	7100

In fact, things get a lot more complicated than this because the figures in the table above assume that each gas has a constant lifetime. This is not true. Some CO_2 is absorbed within seconds of being released; some stays around for hundreds of years… in their climate models scientists calculate GWP based upon lifetimes of 1, 20, 100 and 500 years. There is uncertainty at every stage!

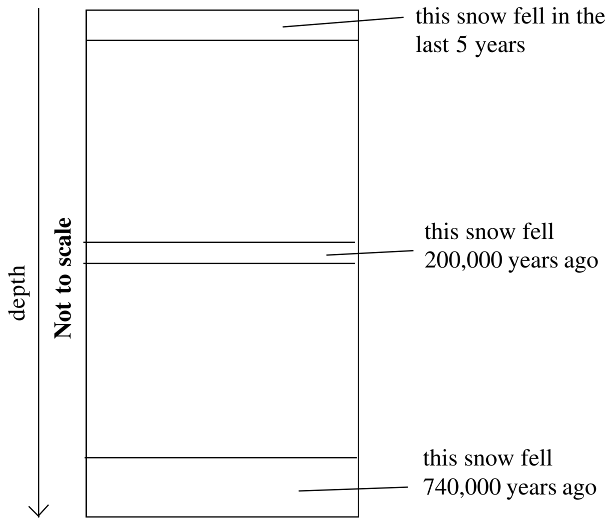
What was the climate like 740,000 years ago?

- Scientists from 10 countries have extracted an ice core 3000m long out of Antarctica
- This represents 740,000 years of snow, with each year preserved as neatly as an annual growth ring in a tree.
- By analysing the gases in each year's deposit we can tell how much CO_2 there was in the atmosphere in that year
- Isotopes trapped in the ice can be used to calculate the atmospheric temperature for each year

Conclusions so far:

- There have been 8 ice ages and 8 warm periods over the last 740,000 years
- Carbon dioxide and methane levels are now the highest they have been for 440,000 years
- There is a close match between CO_2 and air temperature

More information www.antartica.co.uk



Exxon Mobil (EM) and Friends of the Earth (FoE)

FoE have completed a climate footprint on EM

FoE calculated that between 1882-2002 EM produced 20.36 bt of CO_2 = 5% of the entire world total!

EM is responsible for 3.5% of the total temperature increase since 1882. FoE believe that when global climate change catastrophes occur, the people and governments affected will sue whoever is responsible – hence the climate footprint report.

More information: www.exxonclimatefootprint.com

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