- Climate sensitivity and response time depend upon ***climate feedbacks***, which are changes in the planetary energy balance induced by the climate change that can magnify or diminish climate response. Feedbacks do not occur immediately in response to a climate forcing; rather, they develop as the climate changes.

  Fast feedbacks come into play quickly as temperature changes. For example, the air holds more water vapor as temperature rises, which is a positive feedback magnifying the climate response, because water vapor is a greenhouse gas. Other fast feedbacks include changes of clouds, snow cover, and sea ice. It is uncertain whether the cloud feedback is positive or negative, because clouds can increase or decrease in response to climate change. Snow and ice are positive feedbacks because, as they melt, the darker ocean and land absorb more sunlight.

  Slow feedbacks, such as ice sheet growth and decay, amplify millennial climate changes. Ice sheet changes can be treated as forcings in evaluating climate sensitivity on time scales of decades to centuries.

- Most of energy imbalance has been heat going into the ocean. Sydney Levitus has analyzed ocean temperature changes of the past 50 years, finding that the world ocean heat content increased about 10 watt-years, consistent with the time integral of the planetary energy imbalance.
- Levitus also found that the rate of ocean heat storage in recent years is consistent with our estimate that the energy balance of the Earth is now out by 0.5 to 1 W/m^2. Note that the amount of heat required to melt enough ice to raise sea level 1 m is about 12 watt-years (averaged over the planet), energy that could be accumulated in 12 years if the planet is out of balance by 1 W/m^2.

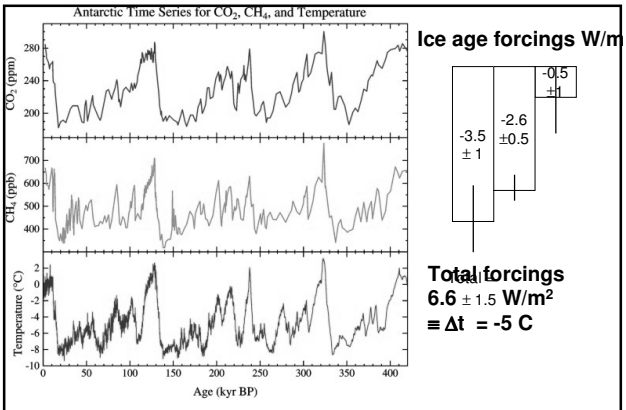
•1 Note that 1 J = 1 W·s, the number of seconds in a year ≈ π × 10^7, and the surface area of the Earth ≈ 5.1 × 10^{18} cm^2; therefore, 1 watt-year over the entire surface of the Earth ≈ 1.61 × 10^{22} J.

- ***Ice melting***: assume that the 10 cm rise in sea level between 1950 and 2000 was due to melting ice (thermal expansion of warming ocean water contributes about half of the rise, but this error is partly balanced by melting sea ice and ice shelves, which do not raise the sea level). If the initial temperature of the melted ice was –10 °C and its final temperature was that of the mean ocean surface (+15 °C), then the energy used is 10^5 cal/g (80 cal/g for melting). The heat storage is thus 10 g/cm2 × 10^5 cal/g × 4.19 J/cal × surface area of Earth (~5.1 × 10^{18} cm2) × ocean fraction of Earth (~0.71) ≈ 1.6 × 10^{22} J ≈ 1 watt-year.

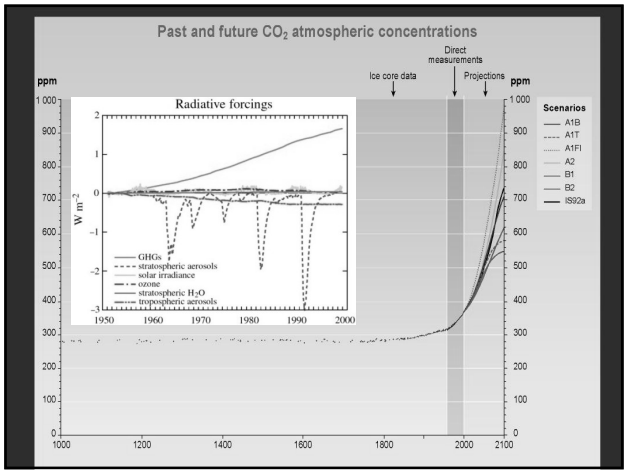
  Air warming: for a 0.5 °C increase in air temperature, the heat storage in the air is: 0.5 °C × the atmospheric mass of air (≈ mass of 10 m column of water ≈ 1000 g/cm^2) × heat capacity air (≈ 0.24 cal/(g·°C) × 4.19 J/cal × surface area of Earth ≈ 0.26 × 10^{22} J ≈ 0.16 watt-year.

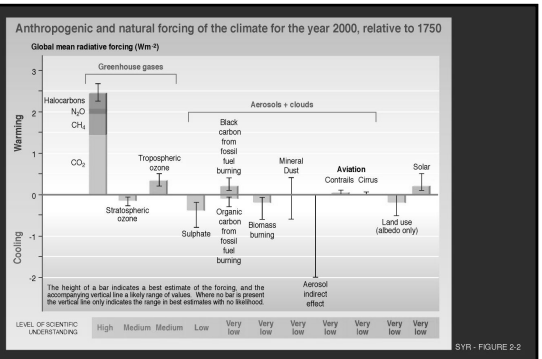
- ***Land warming***: The mean depth of penetration of a thermal wave into the Earth's crust in 50 years, weighted by Δ *T*, is about 20 m. If the Earth's crust has a density of ~3 g/cm3 and a heat capacity of ~0.2 cal/(g·°C), and the fractional land coverage of Earth is about 0.29, then the land heat storage is 2 × 10^3 cm × 3 g/cm^3 × 0.2 cal/(g·°C) × 0.5 °C × 4.19 J/cal × surface area of Earth × 0.29 ≈ 0.37 × 10^{22} J ≈ 0.23 watt-year.

  Ocean warming: Levitus found a mean ocean warming of 0.035 °C in the upper 3 km of the ocean. The heat storage is thus: 0.035 °C × 3 × 10^5 g/cm2 × 1 cal/g × 4.19 J/cal × surface area of Earth × 0.71 ≈ 16 × 10^{22} J ≈ 10 watt-years.



http://naturalscience.com/ns/articles/01-16/ns_jeh2.html#Figure2





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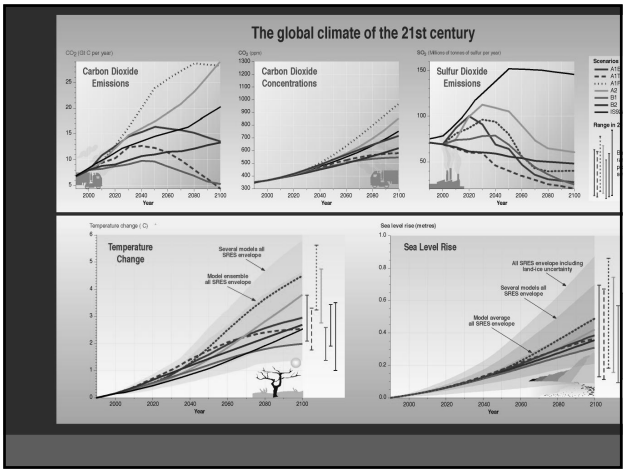
See also:

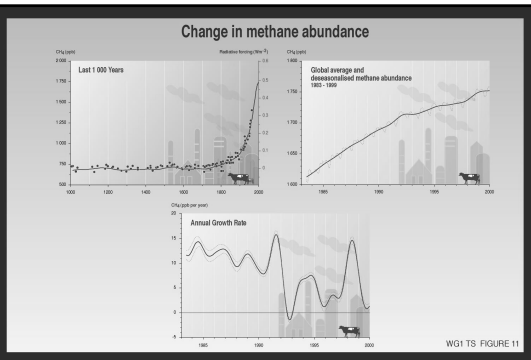
- http://www.junkscience.com/news/robinson.htm
- http://www.ncpa.org/ba/ba230.html
- http://www.ourcivilisation.com/aginatur/moregw.htm

- http://iglobalwarming.info/?gclid=CMit29bE84ICFUKAEAodgCAksQ
- http://www.ipcc.ch
- http://www.metoffice.com/education/links.html#warming

Cost benefit analysis

- The UK's experience allows an analysis – between 1990 and 1999, the UK's greenhouse gas emissions fell by over 13%, the UK economy grew by 49%, employment increased by 4.8%, and UK greenhouse gas emissions intensity fell by 42.6%.
- The cost of a 60% cut in UK emissions would be roughly equivalent to the loss of 6 months growth over 50 years against a backdrop of a tripling in wealth. In other words, people in 2050 would have to wait only an extra 6 months for incomes to reach the level they would have been at if no action were taken.





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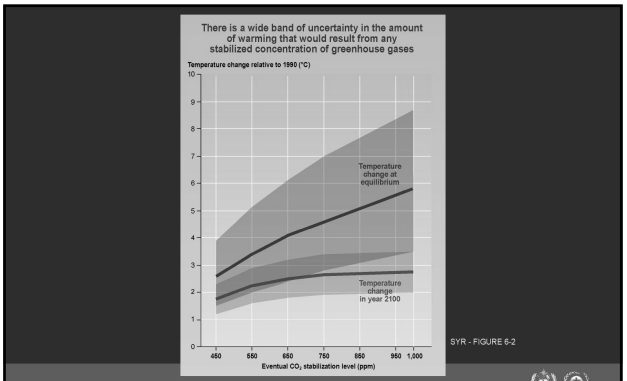

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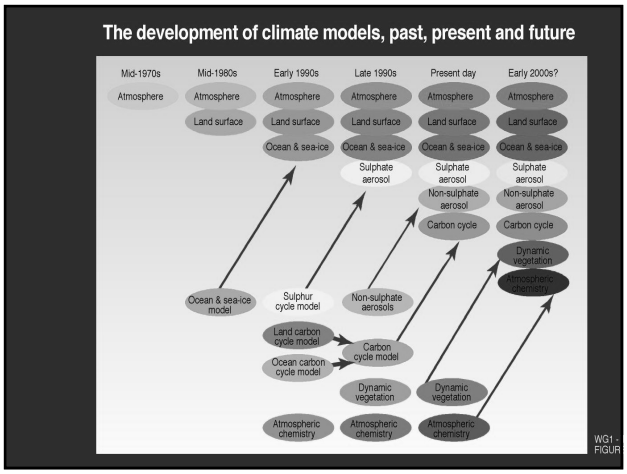
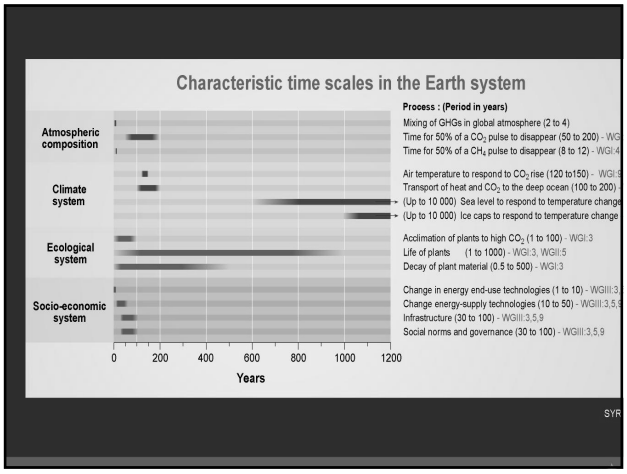
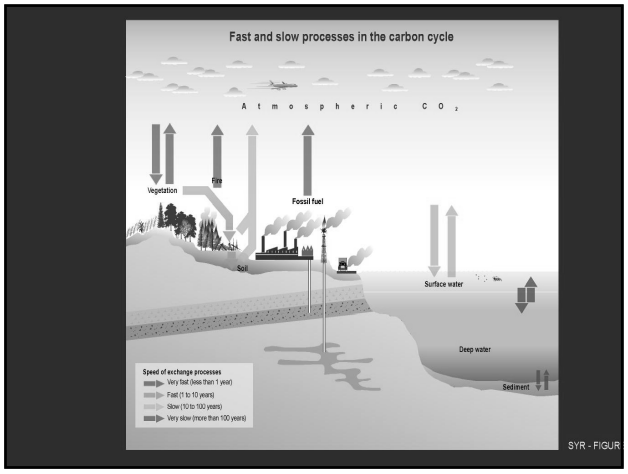


The Time Domain

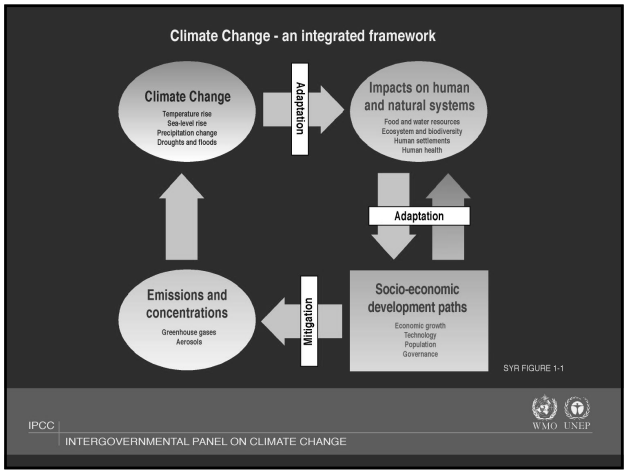
- Different times scales are of crucial importance.
- We have seen many time constants at work so far:
  - Biomass
  - Upper ocean circulation
  - Deep ocean circulation
  - Sequestered time constants
  - Hydrocarbon extraction and costs
  - Uranium extraction and costs





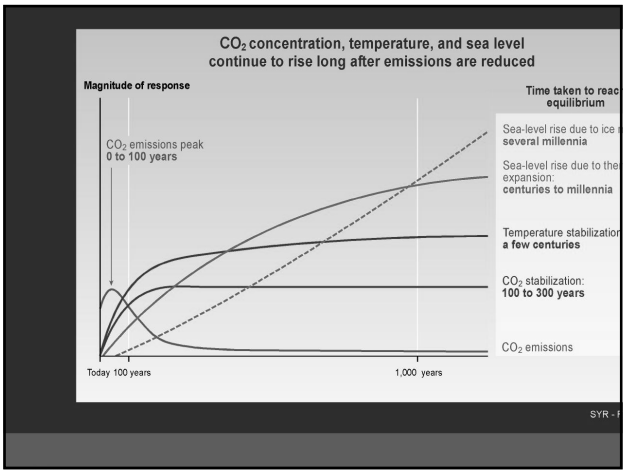
Costs of GW Mitigation vs costs of GW

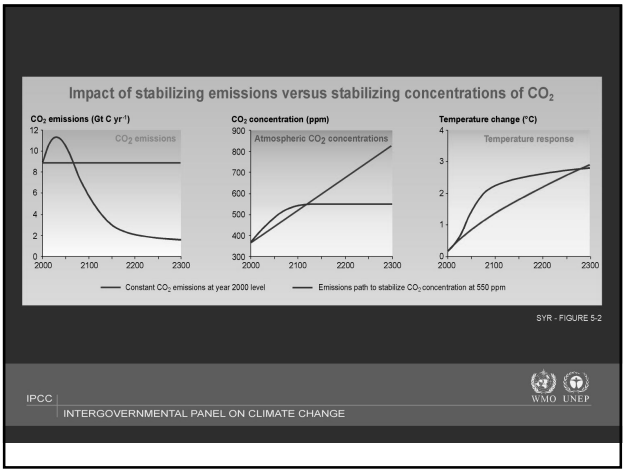
- To analyse the relative costs, the whole lifecycle approach to fuel alternatives must be compared to best estimates of different response scenarios – including that we do nothing at all.
- Costs must cover all aspects of the fuel-society-economics-mitigation interaction

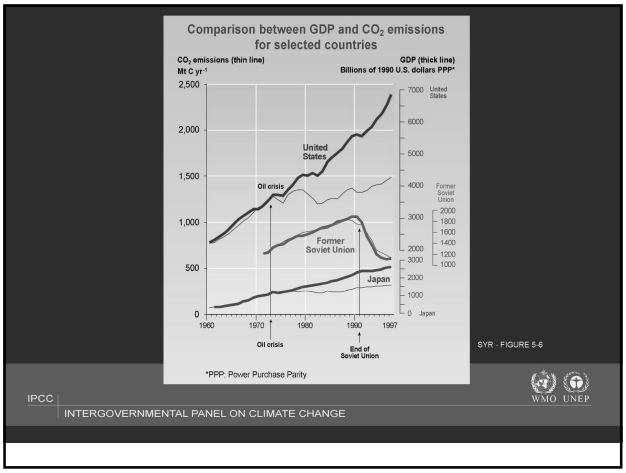


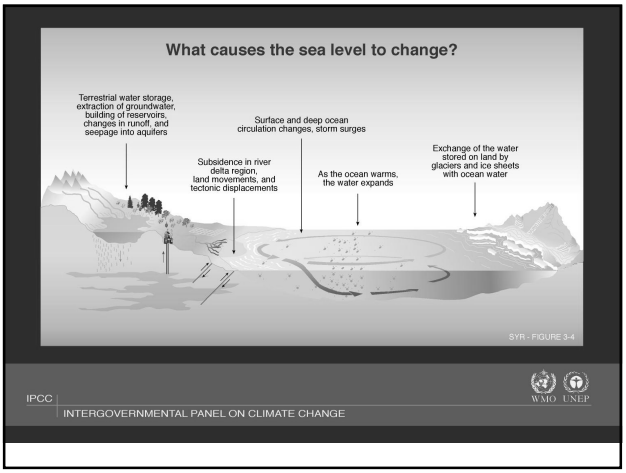
More time constants

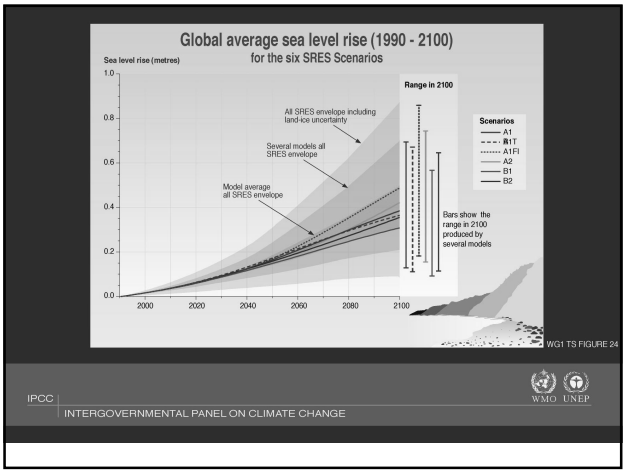
- To allow a proper cost analysis we must also include correlated effects with vastly different time domains – and differing certainty of effect scales.

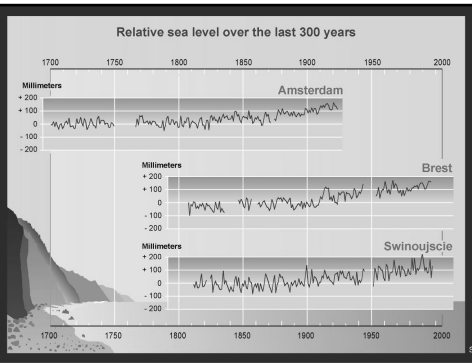












SYR - FIGURE 2-5

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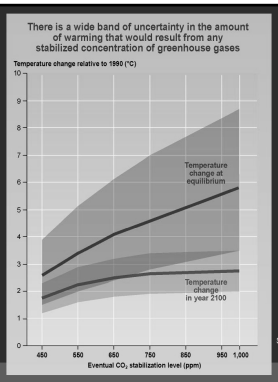

SYR - FIGURE 6-2

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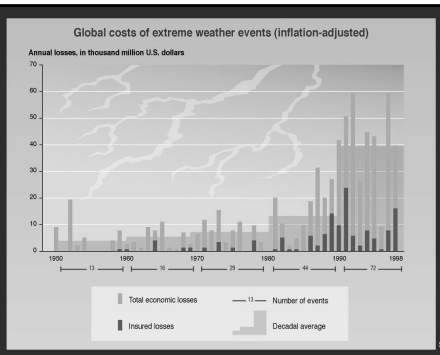

SYR - FIGURE 2-7

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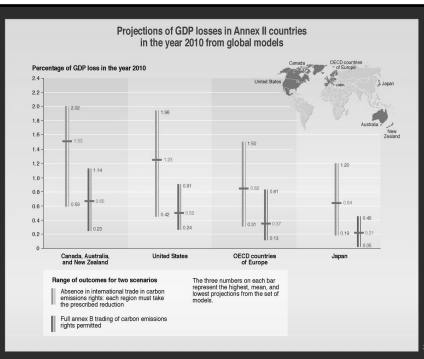

SYR - FIGURE 7-2 a

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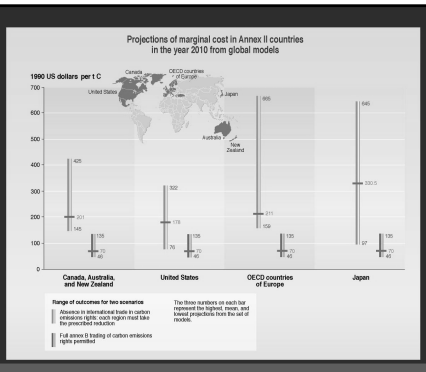

SYR - FIGURE 7-2 b

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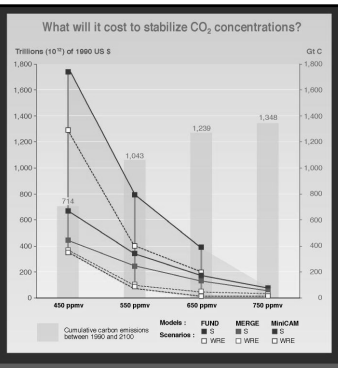

SYR - FIGURE 7-3

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- **UN unveils plan to release untapped wealth of...$7 trillion (and solve the world's problems at a stroke)**
- **By Philip Thornton, Economics Correspondent**
- **Published: 30 January 2006 The Independent**
- The most potent threats to life on earth - global warming, health pandemics, poverty and armed conflict - could be ended by moves that would unlock $7 trillion - $7,000,000,000,000 (£3.9trn) - of previously untapped wealth, the United Nations claims today.
- The price? An admission that the nation-state is an old-fashioned concept that has no role to play in a modern globalised world where financial markets have to be harnessed rather than simply condemned.
- In a groundbreaking move, the UN Development Programme (UNDP) has drawn up a visionary proposal that has been endorsed by a range of figures including Gordon Brown, the Chancellor of the Exchequer, and Joseph Stiglitz, the Nobel Laureate.
- It says an unprecedented outbreak of co-operation between countries, applied through six specific financial tools, would slice through the Gordian knot of problems that have bedevilled the world for most of the last