GREENHOUSE EFFECT: CURRENT KNOWLEDGE AND IMPLICATIONS FOR SOUTH WEST ENGLAND

SUMMARY

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1. <u>**Greenhouse Effect: Definition, History and Recent Developments**</u>. The term Greenhouse Effect refers to a natural process whereby warming of the lower atmosphere is enhanced by the ability of certain trace (greenhouse) gases to absorb and re-radiate long wave radiation emitted from the earths surface. Although recognised for over 150 years the potential impact of these gases, especially CO_2, CH_4 (methane), N_2O (nitrous oxide) and CFCs, has only excited world interest over the last two decades. In this time a variety of scientists have modelled the possible climatic impacts and produced a variety of estimates of likely climatic change. International cooperation has seen the establishment of the Intergovernmental Panel on Climate Change (IPCC) which met in 1990 in Geneva, and has also published the most up-to-date scientific assessment of the problem (Houghton, 1990). In the UK this formed part of the basis for a Report to the DOE by the UK Climate Change Impacts Research Group in January 1991, entitled 'The Potential Effects of Climate Change in the UK'.

2. <u>**Greenhouse Gas Emissions - Predicted Changes and Their Role in the Climate System**</u>. Measurement of the concentration of greenhouse gases is made from ice core evidence and current monitoring programmes. CO_2, which is mainly released due to burning of fossil fuels, has risen from pre-industrial (pre-1765) levels of 280ppmv to 353ppmv in 1990, and accounted for 61% of total radiatve forcing (the amount of extra radiation trapped and available for heating) for the same period. For the most extreme scenario adopted for the future by the IPCC, the Business-as-Usual (BaU) scenario, this value would rise to between 800-850ppmv by 2100. Because of the long atmospheric lifetime of CO_2 of 50-200 years, the time it is retained in the atmosphere and hence is 'active', concentrations are certain to continue to rise, and will be at 575ppmv in 2050. CH_4, although it has a shorter lifetime of 10±2 years, has a greater Global Warming Potential (GWP) relative to CO_2 and is increasing at 0.9% pa, mainly due to agriculture, especially rice paddies. CFCs which derive from propellants and refrigerants have an even higher GWP, up to 7300 times that of CO_2, and have lifetimes of up to 400 years. Thus despite the limitations on use as a result of the 1987 Montreal Protocol the effects will be long lasting. For CFC-11 estimates are for concentrations of 630pptv by 2100 under BaU (1990 - 280pptv). For N_2O which has a range of sources and a lifetime of 150 years concentrations have risen from pre-industrial levels of 285ppbv to 310ppbv in 1990, with an estimate of 418ppbv by 2100. Other trace gases such as stratospheric and tropospheric ozone (O_3), and CO, also increase radiative forcing, but to much lesser extents.

3. <u>**Greenhouse Gas - Climate Links: Climate Models and Predictions**</u>. The influence on climate due to radiative forcing from greenhouse gases is inferred from modelling. Although there is some use of Palaeo-analogue models utilising past climatic evidence, most modelling is numerical using Global Climate Models (GCMs) which attempt to model various aspects of the climate system. The IPCC assessment synthesises the results of 20 models run for a doubling of CO_2 (CO_2x2) to ascertain common trends and results. The recent development of coupled atmosphere-ocean-terrestrial models, which require extensive computer time but are more 'realistic', promises to provide a better model base. There are many problems with GCMs, both due to the need to represent the global scale and due to uncertainties over major feedback processes in the atmosphere which are poorly understood, e.g. the effect of water vapour, of clouds and of the albedo effect of snow and ice. Validation of the model results is achieved by running for current conditions and comparing with observational evidence but this too is made

difficult by limitations of the observational data. At the regional scale there are as yet no models available for the UK; a Meteorological Office model is being developed but is not expected to produce acceptable results until the end of the decade. At the global level the following general predictions derive from the GCMs: temperature - a general global rise between 1.9-4.4°C with a best estimate of 2.5°C, and greater warming at higher latitudes; precipitation - more difficult to estimate, but probably a net increase with greater winter precipitation between 35-55°N; variability - there is no evidence for any change in the nature of climatic variability, but again this is an area of uncertainty.

4. <u>Natural Climatic Variability - Detecting the Influence of Greenhouse Gases</u>. Detection of change which can be 'attributed' to greenhouse warming is made difficult by the natural variability of climate. Observational data to 1990 shows changes which are consistent with some of the model predictions but which are also well within historical variability. Over the last 100 years there has been a rise in global mean temperature between 0.3-0.6°C, but there has been no enhanced warming in higher latitudes. The use of 'fingerprints' for detection, changes that are specific to model predictions e.g. tropospheric warming/stratospheric cooling, has been suggested but these are still too difficult to detect in a system with a high signal-to-noise ratio. Assuming that it will be necessary to see at least another 0.5°C rise in global temperature to be able to detect greenhouse warming, this may be seen by the early 21st century under the BaU scenario. Before then it is very unlikely that it will be possible to confirm any of the predictions of the GCMs.

5. <u>Sea-Level Change</u>. As a result of warming a major area of concern will be possible sea-level rise. Over the last 100 years, despite a very limited global data base, it has been estimated that global sea level has risen at rates of between 0.5-3.0mm $year^{-1}$. 40% of this rise has been accounted for by thermal expansion of the oceans, a similar figure to that for the melting of mountain glaciers and ice caps. Limited data for Greenland suggest a contribution of 20-25% whilst the net contribution of Antarctica has been to remove moisture as the higher temperatures allow greater accumulation of snow, -0.2 to -0.38mm $year^{-1}$. Because of the lags in the response of oceans to climate, future sea-level rise is highly probable as it is an area where there is a 'commitment' to change. By 2030 a 'best estimate' of +18.3cm is predicted (10.1cm - thermal, 7cm from glaciers, 1.8cm from Greenland and -0.6cm from Antarctica). By 2100 sea level could be anywhere between +31-110cm; even if all forcing were to cease by 2030 there would still be a rise of 41cm over present by 2100.

6. <u>Ecosystem Change</u>. The impact of global warming on ecosystems has received less attention than most other areas, although a number of potential changes have been identified - possible increases in productivity and storage of carbon, changes in the distributions of species and communities, and a greater overwintering of pests and pathogens in higher latitudes. There is also a feedback between ecosystems and climate with possible enhancement of the greenhouse warming by changes within ecosystems e.g. the melting of permafrost and changes in tundra areas leading to greater emission of CH_4.

7. <u>Climate and Sea-Level Change in the UK</u>. Although the IPCC data provides a global basis against which the position of the UK can be evaluated, the UK group has derived predictions, or rather scenarios, for the UK based on a selected group of the most advanced GCMs, using the BaU scenario for CO_2x2. In the UK summer temperatures are predicted to rise by levels equal to the overall global figure, +0.7°C by 2010, +1.4°C by 2030 and +2.1°C by 2050. Winter temperatures would show greater warming with a SW/NE gradient and

figures of between +1.5-2.1°C by 2030, and +2.3-3.5°C by 2050. Assuming no change in the distributional pattern of temperature through the seasons the probability of a 1976 'event' would become 1 in 10. Summer precipitation is predicted to be similar to today but with high uncertainty (0±5% for 2010, 0±11% for 2030, 0±16% for 2050). Winter precipitation is similarly uncertain but very likely to rise, +3.3% by 2010, +5.5% by 2030 and +8.8% by 2050. Thus soil moisture will be similar to today during the winter, but there will be a greater problem of soil moisture deficits in the summer. The estimates for sea-level change are very similar to those of the IPCC, +8cm by 2010 (range 4-13cm), +19cm by 2030 (19-29cm) and +31cm by 2050 (15-45cm). There is no basis for predicting any greater intensity of storm events or any greater variability in climate for the UK on the present evidence. The increase in summer temperatures is likely to lead to an increase in demand for water and to greater problems meeting that demand. With a higher probability of warmer summers the increased winter precipitation is unlikely to offset the problem of storage. The increase in temperatures and greater probability of low flows will also have a potential impact on water quality and the ability of rivers to cope with pollutants. Greater stability of water bodies encouraging thermal stratification will also encourage the development of algal blooms. Although there is unlikely to be a problem from an increase in the frequency of extreme events, the possibility of more intense summer storms has to be considered as does greater winter runoff. The main impact of higher sea levels will only be felt at those locations currently under threat from inundation although it will be necessary to survey all other locations which may become more threatened. Only if fresh water extraction takes place near to current sea level will there be a problem in the future.

8. **Points for consideration by the NRA**. It is of major importance that all planning takes into consideration the timescales involved. Up to 2030 the 'best estimate' figures are reasonable planning guides, especially where there are 'commitments to climate change' involved, as in sea levels and probably global temperature. Beyond 2030 the future effect of international responses to an acknowledged warming is likely to influence change and the worst estimates should be very unlikely. Current knowledge is remarkably limited in many areas but the recent impetus given to studies of all relevant aspects means that there will be a considerable expansion of knowledge over the next decade. Thus by 2000 the predictions will be more reliable and available at the regional scale, furthermore by then it should be possible to detect whether warming is actually occurring with greater confidence. For planning therefore it would be sensible to be flexible for the next decade with a view to more concrete responses in the early part of the next century. It will be necessary to develop a series of priorities for action and investment. Of highest priority will be an evaluation of the ability of the regions water resources to meet possible demands up to 2030, given a range of scenarios of climate and demand. There will also be a need to develop models which will ascertain the local effects of increased temperatures on water quality. Although not threatened to the same extent as other areas of the UK there will need to be a review of sea defence schemes to account for estimated levels, at least up to 2030. Because of the need for up-to-date informed decisions it will be advisable to closely monitor developments in the whole field of global warming and to communicate the state of knowledge both within the NRA and to customers and the general public. In the light of ever increasing media coverage it will be vital to be able to respond with convincing and reasoned answers to the inevitable questions and comments that will appear over the next few years.

9. <u>Conclusion</u>. Whilst recognising the potential gravity of global warming for all areas of NRA interest, it should also be noted that not all scientists are as convinced about the threat as those whose results are summarised in the IPCC reports and in the UK Climate Change Impacts Research Group. The whole problem is one which is 'theory-rich and data-poor', and it is only with the course of events over the next 10-20 years that the reality of the climatic responses to the presence of ever-increasing concentrations of greenhouse gases will observed.