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PRIME MINISTER

CLIMATIC CHANGE

In early December the Cabinet Office were asked to prepare a paper for consideration at a meeting of Ministers in early January. This is attached. You will want to look at the covering note by the Cabinet Office. In addition there is a lot of interesting material in the annexes.

(i) Annex A sets out the current scientific assessment of the problem.

(ii) Page 5 of Annex C demonstrates just how important China is in this problem, and pages 13 and 14 indicate the range for the contribution which nuclear electricity could make.

(iii) Page 7 of Annex D draws a pessimistic conclusion of the possible contribution from transport.

(iv) Paragraph 20 of Annex E indicates the conclusions for Britain's flood defences.

(v) Annex F discusses the benefits of converting methane to CO_2.

(vi) Paragraph 16-28 of Annex H indicates the main research priorities.

(vii) Annex I discusses the economic policy implications.

The meeting has been arranged for Thursday 12 January after Cabinet. The Cabinet Office have suggested adding Mr. Baker and possibly also the Secretary of State for Defence, in view of their responsibility for the Meteorological Office. Agree to add Mr. Baker in view of his responsibility for research councils? Adding the Secretary of State for Defence does not seem necessary; we can bring in the Director General of the

Yes

Meteorological Office at the seminar.

The report suggests that Ministers consider setting up a seminar of experts. It will be helpful to have this decided in advance so that preparations can start immediately, eg the issue of invitations and the commissioning of papers. Agree?

The final page sets out ideas for people who might be invited. Any you wish to delete (Porritt?), and any you wish to add (Professor Lovelock?).

AT

ANDREW TURNBULL

23 December 1988

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CABINET OFFICE

70 Whitehall London SW1A 2AS Telephone 01-270

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P 03322

Andrew Turnbull Esq
Principal Private Secretary
10 Downing Street.

22 December 1988

Dear Andrew,

will AT?

CLIMATIC CHANGE

In his letter of 1 December Nigel Wicks recorded the Prime Minister's wish that the Cabinet Office should co-ordinate the preparation of a paper on climatic change for consideration by the Ministers principally concerned at a meeting in January.

This I attach. We have provided an overview of what the problem is, what is being done internationally and nationally to help solve it, and what possible courses of action Ministers might wish to consider, with a view to commissioning further work.

I am copying this letter and the attachment to the Private Secretaries to the Foreign Secretary, the Chancellor of the Exchequer, the Secretaries of State for the Environment, Energy, Trade and Industry and Transport, and the Minister of Agriculture, Fisheries and Food.

Yours ever,

Richard

R T J WILSON

Thank you - it is a marvellous account of issues and proposals for action

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CLIMATIC CHANGE

Note by the Cabinet Office

The Cabinet Office were asked by the Prime Minister on 1 December to co-ordinate a paper on climatic change, covering both the substance and the presentation of Government policies, and taking full account of international aspects. We were also asked to consider how United Kingdom experts outside Government might be involved in the development of policy.

2. This paper has been prepared by a group chaired by the Cabinet Office and including representatives of the Foreign and Commonwealth Office, the Overseas Development Administration, the Treasury, the Departments of the Environment, Trade and Industry, Transport and Energy, and the Ministry of Agriculture, Fisheries and Food. They have prepared the attached Annexes on particular aspects of the problem.

I. **THE PROBLEM (Annex A)**

3. The temperature of the earth's surface depends on a balance between the radiation it receives from the sun and the radiation it emits, mediated by the insulating effect of the atmosphere. Solar radiation is concentrated at visible wavelengths, to which the atmosphere is transparent. But most of the radiation emitted by the earth is at infra red wavelengths. This is absorbed by several greenhouse gases in the atmosphere, keeping the temperature of the surface and lower atmosphere some 33°C above the level it would otherwise maintain and allowing it to support life.

4. The problem is that man's activities since the industrial revolution have been increasing the concentration of the greenhouse gases. The most important are:

i. carbon dioxide (CO_2), mainly from the burning of fossil fuels (currently about 80%) and the destruction of forests (20%). The concentration in the atmosphere is already approaching 30% above pre-industrial levels;

ii. chlorofluorocarbons (CFCs), whose concentration in the atmosphere (entirely artificial) is rising by about 6% per annum. While much less abundant than CO_2, CFCs are about 10,000 times as effective as greenhouse gases;

iii. methane (CH_4), mainly from agricultural sources like rice paddies and livestock. Atmospheric concentrations are rising at about 1% per annum;

iv. nitrous oxide (N_20), probably mainly from the burning of fossil fuels and agriculture. Atmospheric concentrations have been rising by about 0.25% per annum;

v. ozone (O_3) in the lower atmosphere (not stratospheric ozone, which is important in shielding the earth from ultra violet radiation). Concentrations appear to have doubled compared to pre-industrial levels, probably as a result of pollution from the burning of fossil fuels.

By about the middle of the next century the relative contributions of these gases to global warming might be carbon dioxide 64%, CFCs 13% (assuming that the current Montreal limits are fully effective), methane 10%, nitrous oxide 9% and ozone 4%.

5. There is as yet no firm evidence of climatic change resulting from the greenhouse effect. But there is no serious disagreement within the scientific community that man's activities will lead to global warming. Prediction of the magnitude of the change is subject to considerable uncertainty. Work is in hand to reduce this uncertainty, which should lead to better estimates of global warming within about 5 years. But accurate predictions of regional climatic changes are unlikely to be available for about 15-20 years.

6. At present rates of increase a doubling of the effective concentration of greenhouse gases compared with pre-industrial levels is possible at some time between 2030 and 2100. There would be a considerable delay before the full climatic effects were experienced, because of the damping effect of the oceans. But current estimates suggest that the following changes would in time be inevitable:

i. global warming by an average of 1.5-4.5°C. This relatively wide range reflects the considerable uncertainty mentioned above. But even the bottom end of it goes beyond historical experience. For comparison, the temperature in the Ice Age was about 5°C below present levels;

ii. a rise in sea levels by at least 20-140cm, mainly due to thermal expansion of the oceans, which could threaten extensive areas of land, particularly in some developing countries;

iii. regional climate changes, although the details cannot yet be predicted. There might be winners and losers, but much would depend on whether natural, agricultural and social systems could adapt to changes of unprecedented speed.

II. INTERNATIONAL ACTION (Annex B)

7. Climatic change is a global problem. Action by the United Kingdom alone will not have any significant impact. The UK is estimated to be responsible for only about 3% of CO_2 emission from burning fossil fuels. It produces 10% of CFCs but consumes only about 5%. To be effective, action will need to be coordinated internationally. But this will create special difficulties for the less developed and newly industrialised countries (LDCs and NICs). These countries' plans for economic development imply very sharp increases in emissions of greenhouse gases, particularly from burning fossil fuels. Total world emissions are likely to increase substantially as a result, unless there is offsetting action which it will be difficult to persuade such countries to take.

8. A lot of work is already in hand. The most important forum is the Inter-governmental Panel on Climate Change (IPCC), inaugurated in late 1988 by the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO). The United Kingdom is in a strong position to influence this initiative. The Director-General of the Meteorological Office chairs one of three working groups which have been established, we are core members of a second and are participating in the work of the third. The aim of

the IPCC is to report to the Second World Climate Conference in mid 1990 and to prepare interim conclusions including recommendations for international action in autumn 1990.

9. Ministers will wish to note that there are already a number of other initiatives and proposals in this field. They include the French Prime Minister's plan (not yet publicly announced) for a supranational environment authority, Soviet proposals on "environmental security", and proposals for conferences from the Japanese and the Dutch among others. The European Commission are also showing interest in this area. But the UK approach has been to support the work of the IPCC, and to give it a political boost as the international community's chosen forum for tackling climatic change.

III. DOMESTIC ACTION

10. We have already noted that purely domestic measures could have no significant impact on global warming. But if international action is to be effective we will clearly need to commit ourselves to implement the agreed measures in the UK. Ministers will therefore want to review possible domestic measures to identify areas where the UK could be prepared to enter into international commitments. Indeed, the UK and other developed countries may need to give a lead if we are to persuade the LDCs and NICs to participate. In some areas there may be a case for early action to reduce the risk of costly and disruptive measures at a later stage. Most of the measures we could take are however likely to incur extra costs and could affect our international competitiveness. One main judgement for Ministers to make is whether it is worth incurring such disadvantages for the sake of encouraging international action.

11. Annexes C to G contain Departments' assessments of the implications of present policies for climatic change, and what options might be explored to mitigate the greenhouse effect, in concert with other countries where appropriate. Annex H covers research, and Annex I discusses the economic issues raised by climatic change.

a. **Energy** (Annex C)

12. The use of fossil fuels accounts for the great majority of UK CO_2 emissions. Electricity generation is responsible for about 37% of total emissions; other industrial uses of energy for about 20%; domestic and commercial heating for about 20%; and transport (covered below) for about 20%. UK emissions fell between 1979 and 1984. But they have since started to rise again. On a central estimate for economic growth it is forecast that they might rise to 70% above 1987 levels by 2030 unless further action is taken. Burning of fossil fuels also contributes to some of the secondary greenhouse gases; methane, nitrous oxide and tropospheric ozone.

13. Carbon dioxide emissions are an inevitable consequence of burning fossil fuels. But there are possible measures which alone or in combination could help to reduce total emissions:

i. greater energy efficiency. Pricing is the main means of influencing energy efficiency. But options open to the Government include providing further advice and information to improve the working of the market, more research and development, regulation (eg in relation to buildings) and subsidies. Programmes to stimulate industrial innovation and encourage recycling and waste minimisation would also contribute to the more efficient use of energy;

ii. greater use of nuclear electricity generation, over and above what is implied by the non-fossil fuel obligation on the privatised electricity industry;

iii. greater use of renewable energy sources, particularly wind, tidal and geothermal power.

But even if vigorous action were taken in all three areas, current estimates suggest that it would not be sufficient to offset the full increase in emissions which is forecast on the central assumption for economic growth.

14. Another option could be to set taxes or levies on different forms of fuel so as to reflect their greenhouse potential. The aim would be to use the price mechanism to influence the market towards preferred fuels: for example, natural gas, renewables, nuclear. The implications of such an approach are far-reaching, since altering price systems would feed through into patterns of demand; and if measures were taken by one country on its own they could affect international competitiveness. But it would be in line with the Polluter Pays Principle to reflect in costs the externalities which the use of the fuel creates. It is possible that the income from the levies could be recycled to the industry concerned. Any estimates of such costs could be wrong by a wide margin and this would mean that the outcome could be far from optimal. But signals of this kind - even if they only imperfectly reflected costs in prices - could be an important influence on public opinion.

b. **Transport** **(Annex D)**

15. The great bulk of transport's 20% contribution to total CO_2 emissions in the UK is attributable to road transport: rail, shipping and air transport contribute less than 2% of total UK emissions. Consumption of petrol has risen by about 28% over the last decade, despite an improvement of 20% in average car fuel efficiency. Consumption of derv has risen by 50%. The National Traffic Forecasts for Great Britain suggest further increases in vehicle kilometres of 23% (low growth) and 47% (high growth) by 2010, which imply further increases in fuel consumption and CO_2 emissions.

16. Possible measures to curb CO_2 emissions from road transport include:

i. further improvements in fuel efficiency. A 30% improvement is thought to be possible by 2010, provided consumers are willing to accept design changes, eg in transmission systems. But this is likely to be offset in part by action to reduce pollutants other than CO_2, particularly if 3-way catalytic converters are made compulsory: this lends support to the UK's preference for the alternative lean-burn technology;

ii. alternative fuels. Methanol and compressed natural gas are possibilities being developed elsewhere which may have little or no applicability to the UK. Hydrogen is a theoretical possibility, but offers no benefit unless derived from non-fossil fuel sources. Electric power is also an option, if supplied from non-fossil fuel sources, but would require a breakthrough in electricity storage technology;

iii. action to reduce congestion, which leads to waste of fuel. But effective action might encourage more travel, and offset any fuel savings;

iv. more radical measures to reduce demand. These might in principle include restrictions on parking or access (eg to city centres); substantial additional investment in public transport to make it an attractive alternative to private cars; an active fiscal policy to discourage usage, eg through excise duty, vehicle excise duty or car taxation; and charging mechanisms, eg road pricing. But all would have major implications for existing Government policies.

c. **Agriculture, Forestry and Food (Annex E)**

17. Agriculture in the UK is a source of CO_2, methane and nitrous oxide. Quantitative information is scanty but the sector seems to be a relatively minor contributor of all three gases compared with other domestic sources of emissions. Agricultural crops can help to absorb greenhouse gases - notably CO_2 - although quantitative data is again limited. On the evidence so far available, there appear to be few domestic measures which would substantially reduce emissions or increase absorption. However, increased efficiency of energy use in the distribution and food processing industries could play its part in a wider effort to reduce emissions from the transport and manufacturing sectors. In the absence of reliable forecasts of regional climate changes, there is considerable uncertainty as to how these industries could adapt to global warming. But consideration of plausible changes suggests that adaptation would present no great technical problems in the UK. Adaptation would, however, have significant implications both for the Community Agriculture Programme and for European Community and international trade policy.

18. Increased forestry has the potential to mitigate the greenhouse effect, by absorbing additional CO_2 from the atmosphere, so long as the additional wood is harvested rather than burned or allowed to decompose. But the main scope is in the NICs and LDCs and would require a reversal of the present trend to deforestation.

19. There would also be important implications for coastal flood defences from the forecast rise in sea levels which might require expenditure 2 or 3 times the current annual level (£50 million) over the period to 2050.

20. Considerable further research is needed in all these areas.

d. **Waste disposal** (Annex F)

21. Carbonaceous material in municipal and industrial waste is a source of either CH_4 or CO_2, depending on the disposal route. Since CH_4 is some 30 times more effective as a greenhouse gas than CO_2, conversion to CO_2 by burning or disposal management is an obvious option. CH_4 emissions from landfill waste in the UK are estimated to be 3 million tonnes per annum. Conversion of all this CH_4 to CO_2 would have a substantial effect on total emissions of greenhouse gases by the UK. Some action on the collection of CH_4 from landfill sites is already underway, both to deal with the danger of methane build-up and as a positive programme of alternative energy supply. If energy derived from waste methane or direct waste incineration displaces fossil fuel combustion, there is an added bonus in CO_2 reduction. The burning of all waste and waste-derived methane would be a promising route to CH_4 reduction, but it would be a major national undertaking.

e. **Chlorofluorocarbons** (Annex G)

22. Substantial action is in hand both internationally and in the UK to reduce emissions of CFCs. The 1987 Montreal protocol requires reductions of 50% in consumption by 1999: as a result of voluntary action by UK industry we will in fact meet this target in 1989, 10 years ahead of schedule. But developments in the science since Montreal show that tougher measures will be necessary to stabilise atmospheric CFC levels. The Government have therefore called for a

strengthening of the protocol to cut emissions by at least 85% by the end of the century. To underline the importance of a worldwide commitment to reducing CFC's, and in particular to persuade countries like China, India and South Korea to sign the protocol, the Government are hosting a major international conference in London in March 1989. The UK has also offered to host the second meeting of the protocol parties in April 1990, which is expected to take decisions on strengthening the protocol.

f. **Research into the Nature of the Problem (Annex H)**

23. The Annex sets out the considerable amount of international research aimed at improving understanding and prediction of climate change, to which the UK is contributing. Some possibilities for enhancing the UK contribution would be:

i. accelerated development of climate models, to reduce the 5-10 years estimated to be required for substantially improved forecasts of global warming;

ii. more support for ground, air-borne and satellite observations needed to generate inputs to the development and validation of predictive climate models and to ensure early detection of climate change. The UK and France are currently withholding support from a second European Earth Resources Satellite (ERS-2) proposed for launch in 1994, which would aim to secure a continuous series of global observations of some climate processes;

iii. further work on impacts of climate change, and possible responses, where only a modest amount of research is in hand.

There may also be a case for better co-ordination of the UK research effort. Steps to achieve this are being taken at the research level. The Stratospheric Ozone Review Group (SORG), sponsored by DOE and the Meteorological Office, has been a successful arrangement for assessing the results of research on ozone in relation to policy formulation. A similar group might be considered for climatic change.

IV. NEXT STEPS

24. Ministers will wish to consider how policy in this area should be carried forward. The review of international action in section II above suggests that our objectives should be to build on the high ground we have captured in the IPCC; to resist alternative initiatives which would fragment international efforts; and to seek to channel the Panel's work along lines compatible with UK policy priorities. That will require a review of possible domestic action to identify areas where we would be willing to enter into international commitments (section III above). The IPCC is due to produce recommendations for international action in autumn 1990, and Ministers may wish to consider a major new UK initiative to fit in with that timing. We should also recognise that the LDCs, and to a lesser extent the NICs, will face particular problems. They may need assistance, for instance through national and multilateral aid programmes, along the lines of the Prime Minister's initiative on the sustainable use of forest resources.

V. INVOLVEMENT OF EXPERTS OUTSIDE GOVERNMENT

25. We were asked to consider how outside experts might be involved in the development and presentation of policy. It is clearly important to draw on the formidable knowledge of some UK experts, and to enlist their support for the policy which Ministers decide to adopt. The best approach might be for the Prime Minister to chair a seminar with the Ministers most closely involved, to which the foremost national experts could be invited. A list of possible invitees suggested by Departments is attached at Annex J.

(flag F in folder 3)

VI. PUBLIC PRESENTATION

26. Ministers will wish to consider how Government policy on climatic change should be presented, both nationally and internationally. There may be a case for a new policy statement, building on what has already been said, for instance in response to the Brundtland report, if only to pull together in one document all the action which the UK has in hand to help mitigate the greenhouse effect. Possible vehicles include:

i. a White Paper;

ii. a "glossy" policy document, similar to the "Action for Cities" document;

iii. Ministerial speeches.

VII. CONCLUSION

27. Ministers are invited:

i. to indicate those aspects of UK domestic policy and research on which they would wish further work to be carried out. This should help to identify areas where the UK could support international action (paragraphs 10 to 23, Annexes C to I);

ii. to agree that the UK should support the existing initiatives under the United Nations Environment Programme (UNEP) and the World Meteorological Organisation (WMO), including the Intergovernmental Panel on Climatic Change (IPCC) in which we already have a strong position, as the main focus for international activity (paragraph 24);

iii. to consider whether a major new UK initiative might be timed so as to fit in with the international activity already under way (paragraph 24);

iv. to consider whether UK experts outside Government should be involved in the development and presentation of Government policy through a seminar to be chaired by the Prime Minister (paragraph 25);

v. to consider how they would wish to present policy on climatic change (paragraph 26).

CABINET OFFICE

December 1988

CONFIDENTIAL

ANNEX A

CLIMATIC CHANGE : THE PROBLEM

Note by the Department of the Environment

HOW SERIOUSLY SHOULD CLIMATE CHANGE BE TAKEN?

1. There is no serious disagreement within the scientific community that man's activities will increase the average temperature of the world's atmosphere. The basic phenomenon, a steady increase in the atmosphere's concentration of "Greenhouse Gases" since the industrial revolution, is well documented. The essential physics of the process, by which these gases alter the balance of incoming radiation from the Sun and radiated heat from the Earth, is simple. The complexities introduced by circulations in the atmosphere and its interactions with the sea and land, make prediction of the magnitude and timing of global warming subject to considerable uncertainty. Nevertheless, scientists are in agreement on the work necessary to reduce these uncertainties, rather than in dispute about whether or not there will be change.

2. Historic and pre-historic evidence shows that climatic change is the norm rather than the exception, but that the magnitude, direction and speed of the changes predicted for the future are unprecedented in man's experience. Over the last million years, there have been 8 to 10 ice ages, distinguished by average global temperatures some 4 to 5^{o}C below that of today. The last ice age began its decline about 15,000 years ago glaciers retreated from Britain some 9,000 years ago. The growth of modern civilization during the last 5,000 years has taken place during an inter-glacial warm period, within which a number of periods distinguished by high or low average temperatures can

be identified. The "Medieval Warm Period" from about 1000 to 1400 AD saw vineyards in England and the colonization of Greenland by the Vikings. The "Little Ice Age", from about 1500 to 1700 AD saw the Thames Frost Fairs and icebergs off Norway. In both cases, the maximum variation of average temperature was less than one degree and the rate of change about 0.5^{o}C per century.

3. By contrast, the current range of predictions for global temperature rise is between 1.5 and 4.5^{o}C, likely to occur before the end of the next century. This is both a faster rate of change and a higher average temperature than any experienced in historical times.

HOW IS MAN INFLUENCING CLIMATE CHANGE?

4. The temperature of the Earth's atmosphere results from an equilibrium between the radiation received from the Sun and the radiation emitted by the Earth. The Sun's radiation, being from a very hot object, tends to be at high energy, most obviously in the form of visible light. The radiation of the relatively cool Earth, on the other hand, is of lower energy, sensible as infra-red heat radiation. The "Greenhouse Gases" in the Earth's atmosphere affect the equilibrium temperature because they are largely transparent to the incoming, high energy radiation from the Sun but absorb and re-irradiate some of the low energy radiation back to the Earth. Increasing the concentration of greenhouse gases means that the Earth's average surface temperature will rise, increasing the amount of radiated energy necessary to overcome the insulating effecting of the atmosphere until a new equilibrium is reached.

5. The "Greenhouse Effect" is not new. Without it, the World would be colder by over 30^{o}C. The Earth's atmosphere has always contained "Greenhouse Gases"; water vapour (H_2O), carbon dioxide (CO_2) and methane (CH_4), for example. The effect of green plants in reducing the amount of CO_2 in the atmosphere has probably been crucial to maintaining a relatively stable atmospheric tempera-

ture as the Sun's output has gradually increased. Current concern, however, is centred on the rapid increase in greenhouse gas concentrations, over and above those that are "naturally" present, due to man's activities.

6. The degree to which any particular greenhouse gas effects global warming depends on two factors; its relative effectiveness in blocking the radiation from the Earth and its concentration in the atmosphere. Taking both factors into account, the principal greenhouse gases to which man contributes, (with an indication of their potential relative impact on global warming by about the middle of the next century) are; carbon dioxide CO_2, (64%), Chloro-fluorocarbons, CFCs, (13%, assuming the Montreal Protocol is effective), Methane, CH_4, (10%), Nitrous Oxide N_2O, (9%), and Ozone, O_3, (4%). Conventionally, the combined effect of these gases and changes in their atmospheric concentration are referred to as an "equivalent" amount of CO_2. Hence an "effective doubling" of greenhouse gases may comprise a less-than double increase of CO_2 but additional contribution for the other gases.

7. **Carbon Dioxide** (CO_2)

Before the industrial revolution, atmospheric CO_2 levels are estimated to have been around 270 parts per million (ppm). Since 1957, measurements made at Mauna Loa, on Hawaii, have shown a clear increase of about 0.4% per year up to the present. The current concentration is close to 350 ppm.

8. Burning fossil fuels accounts for about 80% of man's CO_2 emissions. In 1950, worldwide fossil fuel CO_2 emissions were about 1,619 million tonnes (expressed as carbon). By 1980, they were 5,170 million tonnes. The annual rise in atmospheric CO_2 is equivalent to about half this annual emission.

9. The destruction of forests also contributes to CO_2 emissions when the carbon locked up in trees is released on burning. The amount is difficult to estimate, but currently could be as high as 25% of the emissions from fossil fuels.

10. **Chlorofluorocarbons** (CFCs)

CFCs are entirely man-made compounds used as aerosol propellants, refrigerants, solvents and foam blowing agents. Their concentration in the atmosphere has been steadily rising at about 6% per year, as shown by measurements made on the West Coast of Ireland, now funded by the DoE. While they are far less abundant, their effectiveness as greenhouse gases is as much as 10,000 times that of CO_2.

11. In contrast to CO_2, which has a relatively fast turnover rate in the atmosphere due to the activity of the biosphere, CFCs have atmospheric lifetimes of around 100 years. Virtually all emissions will continue to produce changes in atmospheric concentrations as the system is far from a "steady state".

12. **Methane** (CH_4)

CH_4 is currently rising at about 1% per year. Ice core data shows this to be an accelerating trend from around the middle of the 18th century.

13. The predominant source of man made methane is probably agriculture with rise paddies and livestock, both closely linked with increasing population, being important factors. Combustion processes emit some methane, and in the industrialised world natural gas losses and CH_4 generation from land-fill waste are significant. The residence time of CH_4, and hence its equilibrium concentration in the atmosphere, might be increased by a subtle effect of primary pollution, in particular carbon monoxide from cars, which might lead to a reduction of the concentration of hydroxyl radicals in the atmosphere. As these radicals are involved in the mechanisms that destroy CH_4 in the atmosphere, their lower concentration would mean longer CH_4 atmospheric lifetimes.

14. **Nitrous Oxide** (N_2O)

N_2O has been increasing by about 0.25% per year. Man's activities contributing to this include combustion of fossil fuels, biomass burning and agricultural practices but current understanding of the scale of emissions and the relative importance of different sources is poor.

15. **Ozone** (O_3)

In the Earth's atmosphere, ozone is mainly found in the stratosphere, above about 10 kms. However, there is a substantial "background" concentration in the lower atmosphere, (the troposphere), and it is here that ozone has the principal effect as a greenhouse gas.

16. There is evidence from measurements made at several locations at the end of the last century that the level of tropospheric "background" ozone may have doubled in the last 100 years or so. Man-made emissions of hydrocarbons and, more particularly, nitrogen oxides from fossil fuel combustion as precursors of ozone production are the chief suspects.

CAN WE CALCULATE WHAT MIGHT HAPPEN?

17. Using very large computer models of the Earth's atmosphere, called General Circulation Models (GCMs), the basic physics of the greenhouse gases can be combined with the additional "feedback" factors, such as increased water vapour, clouds and snow, to give estimates of global temperature rise. Because our understanding of interactions between the atmosphere and the oceans and of cloud and snow feedback mechanisms is limited these predictions are subject to considerable uncertainty over how great that temperature rise might be.

18. As well as the magnitude of the effect, the rate at which it will take place is uncertain. Most calculations to date start by setting the effective greenhouse gas concentration at double

pre-industrial revolution levels and proceed to calculate a new equilibrium temperature. The surface layer of the oceans, however, is a very large thermal mass that will take time to heat up and will therefore delay atmospheric warming.

19. A significant reduction in the uncertainty of temperature rise predictions on a global basis is probable by the end of the next 5 years, but prediction of the likely changes in climate for specific regions are much more complicated and cannot reasonably be expected with any certainty within 15 to 20 years.

20. **Global Average Temperature Change**

Results from a wide range of GCM models using many approaches to describing cloud cover, snowfall and other feedback variables, have been intensively analysed over the last 2 years. There is a high degree of concensus that the "best-guess" range for a rise in equilibrium global temperature if the effective concentration of greenhouse gases doubles, is 1.5-4.5^{o}C. Even at the bottom of the range, this goes beyond human experience in historical times and at the top end has rarely been met with in palaeological records.

21. An effective doubling of greenhouse gas concentrations is likely, at present rates of increase, somewhere between 2030 and 2100. The damping effect of the oceans would defer the full resulting temperature rise by perhaps 50 years but this would be only a delay. The world would be committed to this full temperature rise at some future date, just as we now could be committed to a temperature rise of up to about 1^{o}C implied by the increase in greenhouse gas concentrations since the industrial revolution.

22. **Sea Level Rise**

A global equilibrium temperature rise of 1.5-4.5^{o}C implies an eventual rise in sea level of 20cm to 1.4m resulting from thermal expansion and melting of land-based ice such as glaciers. The full effect will, like the global temperature rise, be delayed beyond the time of doubling effective greenhouse gas concentration, due to the time taken to warm the oceans. The lower end of the predicted rise is similar to the 30cm per century assumption already built into the Thames Surge Barrier. It is conceivable that technically advanced countries could cope with the additional rise on a 50-100 year time-scale. At the other extreme of prediction, some low-lying developing countries would lose extensive areas of their inhabited and agricultural regions and there would likely be significant problems of salt water intrusion into freshwater supplies affecting all countries. Some have voiced fears that the antarctic ice cap might become unstable and slip into the sea, causing sea level rise of several metres. It is also possible, however, that increased snowfall due to higher evaporation and atmospheric moisture content, could stabilise the ice cap. In any case, no one expects such an event to occur before several hundred years.

23. Regional Climate Change

Specific regional "forecasts" are unlikely to be possible for 15-20 years. However, some broad generalisations are possible. Temperature changes at the poles are likely to be greater than at the equator. While overall rainfall should increase due to higher evaporation rates, the distribution could be uneven, both in space and time. Also, soil moisture in the crucial growing periods is the key parameter and this could fall even in higher rainfall areas.

24. Natural ecosystems can adapt to climate change, and indeed most have in the past. Forests have changed their main growing areas, for example. Estuarine systems have relocated and reformed as sea levels have altered and land masses risen or fallen. However, the rate of change predicted, even with the damping effect of the oceans, may be too fast for some systems to adapt. Furthermore, in a densely populated world, there are limited areas for natural ecosystems to move into.

25. Agriculture, similarly, might in principle be able to cope by moving the main production areas, but the socio-political implications are vast, besides there being no guarantee that overall productivity would be conserved. There are likely to be winners and losers in climate change, but there can be no assurance that the outcome will overall be favourable.

26. Regional climate change may also include changes in the frequency of extreme events. Planning and coping with drought, winter extremes of cold, intense rainfall and high winds could be as demanding as a change in average conditions.

27. Because of the 15-20 year time-scale for improving our understanding of regional changes, research in the immediate future will have to assume a range of possible futures in an attempt to predict the most critical areas and the worst outcome that we risk.

CAN WE DETECT CLIMATE CHANGE ALREADY?

28. Global circulation models, with an allowance for the damping effect of the oceans, would predict that the atmosphere should have warmed by 0.3-0.7^{o}C over the last 150 years. The global temperature trends available, which in the case of those assembled by the Meteorological Office go back 130 years, show a rise of about 0.5^{o}C. However, the variations in the record mean that the predicted rise of 0.3-0.7^{o}C is not statistically identifiable. The most we can say is that the model predictions are consistent with the past record. Looking to the future, the models would not predict the greenhouse temperature rise to be statistically clear for a decade or more.

29. There have been claims that recent extreme climatic events, such as the drought in North America, are early signs of climate change. Climate statistics, however, do not support the hypothesis that climatic extremes have yet become more frequent or more severe.

30. CAN WE STABILISE GLOBAL WARMING?

Mid-Latitudes have sustained temperature drifts in the region of 0.2°C per decade over several decades without appreciable evidence of stress, although in some cases (such as forests) coincident changes in other factors such as rainfall are equally important. If we take this rate as a guide value, it would imply a maximum rate of global CO_2 emission growth of about 1% per annum assuming methane growth was uncontrollable, the impact of CFCs was eliminated by a second stage of Montreal and ignoring the impact of N_2O and ozone. This is 1/3rd to ¼ the current rate of growth of man-made CO_2 emissions. Further, if we wished to stabilise the warming effect of greenhouse gases at some value, we would need to reduce global emission rates to the levels at which these gases are removed from the atmosphere by natural processes. Estimates are most advanced for the CFCs where an 85% reduction on current levels would be necessary. Figures for CO_2 emissions are subject to considerable uncertainty, but a rate of emission at least as low as half the present rate of emission might about equate with the rate at which CO_2 is currently dissolved into the deep ocean.

CLIMATIC CHANGE: INTERNATIONAL ACTION

Note by the FCO/ODA

1. Our aim has generally speaking been to use existing fora and give political impetus to work already going on, starting or being contemplated.

2. The most important is the Inter-governmental Panel on Climate Change (IPCC), whose establishment was agreed in 1987 by the United Nations Environment Programme (UNEP) and the World Meterological Office (WMO) but whose first meeting, effectively starting its work programme, was only in November 1988. At that meeting the panel set up three working groups to:

(1) assess available scientific information (chaired by Dr John Houghton, Director of the UK Met. Office);

(2) assess environmental and socio-economic impacts (chaired by the USSR);

(3) formulate response strategies (chaired by the US).

3. The IPCC immediately agreed:

- to activate the three Working Groups;
- to hold a second session in mid-1989;
- to report to the Second World Climate Conference in mid-1990;
- to hold a third session in Autumn 1990 to consider the Working Groups' reports and prepare interim conclusions.

The election of the UK to the Chairmanship of Working Group 1 ensures the UK has a continuing high-profile involvement in the Panel's work and provides an opportunity for the UK to direct an important area of scientific work of global importance. Successful completion of the task allotted to the Working Groups in the time-scale envisaged will require a significant effort by the Met Office and others in the UK, as well as a major co-ordination exercise to make the best possible use of available international information and expertise. The UK is a core member of Working Group (3), and will participate in Group (2). The existence of the IPCC will serve to co-ordinate much of our thinking in the UK in the coming months.

4. On 23 November, the Second Committee of the UN General Assembly adopted a Resolution (which we had substantially redrafted and co-sponsored) on the Protection of the Global Climate which gives impetus to the work of the IPCC and avoids the establishment of new fora which might detract from the Panel's work.

5. More generally, the strategy of the United Nations system is based on the need to increase understanding of the world's climate system and to apply that understanding to human activities. This strategy is expressed through the World Climate Programme (WCP), initiated by the World Meterological Organisation (WMO) and involving several other UN agencies and the International Council of Scientific Unions (ICSU). The WCP has four components:

(i) World Climate Data Programme

(ii) World Climate Application Programme

(iii) World Climate Research Programme

(iv) World Climate Impact Studies Programme

The World Climate Data Programme and the World Climate Application Programme are concerned, respectively, with the assembly and availability of climate data sets, and the use of knowledge about climate to increase the safety and economy of human activities. The World Climate Research Programme addresses, ia, the predictability of behaviour of the linked atmosphere-ocean-ice-land surface system on regional and global scales and the influences on climate of global changes in the composition of the atmosphere. The World Climate Impact Studies Programme (WCISP) addresses the effect of climate change on ecosystems and human activities. The emphasis of the WCISP has shifted strongly in recent years towards assessment of the impacts of climate change due to the increasing burden in the atmosphere of greenhouse gases and thus a major part of the WCIP is related to assessing the effects of climate change on human activities.

6. The UK gives particular support to UNEP and WMO (which are two of the more effective UN agencies) and makes substantial contributions - compared with other countries - to both organisations. The UK's contribution to UNEP in 1988 was £1.25m (a 25% increase over 1987) and to WMO in 1988 was £800,000. Contributions to both agencies are made to their general funds, not to specific projects or budget lines.

7. On 16 December the European Community and most member states ratified the Montreal Protocol to the Vienna Convention for the Protection of the Ozone Layer, on substances that deplete the ozone layer. (The one or two laggards should ratify by the end of 1988). The Protocol is due to enter into force on 1 January. It provides for the production and consumption of CFC 11, 12, 113, 114 and 115 to be reduced by 50 per cent in three stages by 1999. It also requires production and consumption of halons 1211, 1301 and 2402 to be frozen from 1992. The Protocol provides for these measures to be reviewed in 1990 and every four years thereafter on the basis of available scientific, environmental technical and economic information. The UK will host the 1990 review conference, provisionally scheduled for April 1990 in London. The British Aerosol Manufacturers Association has announced its intention of phasing out non-essential use of CFCs as populants by the end of 1989. Other user industries are also taking steps voluntarily to reduce CFC and halon use as far as possible.

8. The second report of the Stratospheric Ozone Review Group (SORG: an advisory body set up by the DOE and Met Office three years ago) published in October 1988 warned of the need for more stringent measures than are required by the Montreal Protocol. The Government immediately accepted the firm evidence that, as an essential step to prevent further depletion of the ozone layer, we must stabilise chlorine in the stratosphere. To achieve this Lord Caithness called for CFC emissions to be reduced by at least 85 per cent and as soon as possible, in the light of the availablility of substitutes,

alternative technologies and the essential needs of industry. This was subsequently defined as by the end of the century. Lord Caithess proposed that the timing of the 20% and 30% cuts provided for in the Protocol should be brought forward. When he sent the report to all EC Environment Ministers Lord Caithness urged that the UK's stance should be adopted by the EC as its approach to the first review of the Protocol. At the Environment Council on 24 November a number of Member States supported the UK line but it proved impossible to reach a consensus owing to the recalcitrance of Spain and France. The UK is seeking to ensure that the EC adopts a position in line with UK thinking at the next Environment Council in March 1989.

UK Initiatives

9. On 23 November the Secretary of State for the Environment announced his intention to host a major International Conference on CFCs and the Ozone Layer in March next year. Invitations have been delivered to all UN member states, and the initiative has been welcomed by the Executive Director of UNEP, whose organisation will be associated with the Conference. Our two main objectives for the conference are:-

(a) to convince non-OECD countries that they will not lose out if they agree to work towards a CFC-free world, and that new products and processes from industry can be made available to them in reasonable quanitites and at affordable prices. Put simply, developing countries do not need to go through a CFC phase in realising their economic growth; and

(b) to mount a showcase to demonstrate how world industry is working to reduce dependence on CFCs by more careful use, by developing substitutes or by adopting CFC-free technologies.

10. The intended outcome of the Conference would be a political declaration to give a boost to the first meeting of the Montreal Protocol contracting parties in Finland in April 1989 and to subsequent follow-up action.

11. The Government generally welcomed the Brundtland Report on Sustainable Development and published a full response in June. We are one of only a handful of countries so far to have done this. This year's UNGA has been discussing the terms of reference for a Conference in 1992, the 20th anniversary of the landmark Stockholm Environment conference of 1972, which would also follow up major aspects of the Brundtland Report. It has however proved difficult to agree on a satisfactory title or terms of reference, and the resolution adopted succeeds in dissatisfying developed and developing countries alike, but is not actively harmful.

Other initiatives

12. The French Prime Minister has, in a series of (so far private) approaches to a dozen or so Heads of Government including our own, proposed a new International Environment Authority with supranational powers. The initiative seems to be M. Rocard's own, and knowledge of it is limited both within the French Government and nationally. Our first reaction has been unenthusiastic, the Prime

Minister has sent a very careful reply saying that M. Rocard's central proposal, for a new international institution endowed with considerable powers, including coercive ones, raises very complex issues, including sovereignty, the relationship with existing institutions and agreements etc. We hope to channel the idea, if it does run, into the UN system.

13. In addition to proposals on similar lines to the above for new institutional arrangements (put forward recently by eg the USSR and Italy), in recent years there have been calls for a Global Convention on the Atmosphere, along the lines of the Vienna Convention on the Protection of the Ozone Layer. The concept has fairly broad international support but work has not yet begun on a draft. It was a major topic at an international conference held in Toronto, Canada, in June 1988 ("The Changing Atmosphere: Implications for Global Security") at which it was proposed that a global convention should emphasise such key elements as the free international exchange of information and the support of research and monitoring; and provide a framework for specific protocols for addressing particular issues, such as climate, taking into account existing international law. The Toronto Conference envisaged that its proponents should pursue the proposal through a series of further conferences already proposed in 1989-90, with a view to having the principles and components of a convention considered at the United Nations Conference on the environment in 1992 (para 11). This proposal will doubtless also be considered by the Inter-governmental Panel on Climate Change (see para 2 above).

14. The UK has not taken a position on a global convention on the atmosphere. Before doing so, we would wish to ensure that (a) a convention is necessary, and (b) that a convention would not prejudice our other interests. There is a significant head of steam building up behind the proposal and, no matter what our views, some sort of international convention is probably inevitable. Our priority should be to see that work on it follows logically from current work on the science rather than preceeding it.

15. The Vancouver CHOGM established an Expert Group to examine the implications for Commonwealth countries of rises in the sea-level and other natural disasters resulting from possible climate change. The Expert Group is chaired by Dr Martin Holdgate, present Director General of the International Union for the Conservation of Nature and Natural Resources and ex-Chief Scientist at the Department of the Environment. He will need to ensure that his group does not duplicate work done or being done elsewhere.

16. In the non-governmental arena, the International Geosphere - Biosphere Programme links the scientific community and specialist agencies in a major programme to elucidate how changes in the physical world, such as climate change, will affect the sustainability of development and the patterns of planetary life. The Royal Society is the focus for the UK's involvement in the Programme. NERC provides funding for this and is currently seeking additional financial resources to increase UK participation in the IGBP.

17. As discussion in the UN and other fora develops, the attitudes of other countries are becoming clearer. Some, like Malta, the Netherlands and Canada, are taking positions at the front of the pack and will press for firm action in the comparative short-term, backed-up by new legal instruments (eg a Convention on the Atmosphere). Others, such as the US, support the more measured, practical approach which we have taken to date. There will be many in the G77 who, from the back seat, will try to place responsibility firmly on the West (or North) but several G77 states, threatened by the possible consequences of, eg, sea-level rise will be in the vanguard for decisive action in the short-term.

Third World Aspects (including Tropical Rainforests)

18. Economic growth is high on the agenda of developing countries. Rapidly increasing populations and economic growth will increase their energy demands - primarily involving fossil fuels given the practicable options available to them. This and the process of development which leads to higher standards of living and consumption will result in a growing contribution from developing countries to the greenhouse effect. (This is likely to be compounded if, for example, countries such as China and India do not take action on CFCs to implement the Montreal Protocol).

19. Current technology provides few affordable options or solutions for developing countries other than the important one of achieving efficient use of fuels and power in all sectors of their economies.

The issue of population growth has been seized by many developing countries because they have recognised it is in their own interests to do so. Other issues will be much more difficult, mainly because there are no readily available alternatives and their pursuance is intimately bound up with the growth options available to them. Curtailing their use of energy or slowing down economic growth will be unacceptable to them; while some agricultural production systems do produce significant amounts of methane eg, rice production, thus adding to global warming, it would be inconceivable to expect developing countries to reduce food production. Hydro-electricity is location specific (and large dams have their own environmental costs) and other renewable sources of energy have only limited potential for providing large-scale alternative supplies. Certain specific problems eg. CFCs are less insoluble because they are potentially affordable and technically known.

20. Set against a reality of scarce financial resources, little prospect of additionality and a problem which they may perceive as mainly created by industrialised countries and where remedial actions may have little apparent or immediate benefit nationally, few, if any, developing countries can be expected to respond positively and reallocate existing resources. There is little evidence that unless substantial additional resources or other immediate benefits are linked to solutions developing countries will be willing or able to pursue them.

21. If developing countries are to be persuaded to take action, these issues will have to be addressed internationally and handled

sensitively. The developing countries' scientific and technical community needs to be involved as fully as possible to ensure that they have an authorative voice with their own Governments. Further research on global climatic change and energy needs to cover carefully the implications for developing countries partly to ensure that the whole process provides as much convincing evidence as possible on why it is in their own interests to take certain actions such as increasing the efficiency of energy use and transformation. Technological collaboration will be required to help them with implementation.

22. Scientists estimate that up to 20% of current total man made emissions of carbon dioxide has come from the global destruction of forests thereby adding to the greenhouse effect. Destruction of the tropical rainforests has particularly captured public concern though mainly because of issues such as wasteful use of resources loss of genetic diversity and habitats rather than because of climatic change. Tackling deforestation is as much to do with avoiding environmental degradation, (and consequences such as soil erosion and flooding), and preserving genetic diversity as with the contribution to the greenhouse effect. Reafforestation will only have a small and gradual impact on carbon dioxide levels.

23. The ODA is already pursuing the Prime Minister's pledge that we will direct more of our bilateral aid to encourage the wise and sustainable use of forest resources. This links in with the climatic change issue but our own bilateral aid cannot have an

appreciable impact on the rainforests of Amazonia or non-Commonwealth Central Africa, though other aid donors and, to a limited extent, NGOs operate here.

24. In any event the solution lies primarily in the Governments of the countries concerned adopting firm though affordable policies. They need to increase their capacity to manage and monitor forests and develop alternative exports. The latter in turn relates to international trade policies and protectionism not to mention existing debt burdens.

25. The Tropical Forestry Action Plan (TFAP) and the International Tropical Timber Organisation (ITTO), which we strongly support, our two key international channels for addressing forestry issues.

MAED

13 December 1988

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ANNEX C

CLIMATIC CHANGE: THE ENERGY SYSTEM IMPLICATIONS
Note by the Department of Energy.

SUMMARY

Fossil fuel combustion, expected to continue rising in line with economic growth and demographic trends, produces CO2 and is responsible for about half the postulated global warming threat. Energy related emissions of other gases are minor contributors. Although rising in absolute terms the proportion of energy related CO2 emissions from OECD countries has been falling and this trend is expected to continue. The current UK contribution to global CO2 is about 3% and could rise from its present 171 million tonnes to perhaps 280 million tonnes by 2030.

Technologies for the removal and storage of CO2, which is an unavoidable product of combustion, do not look promising. There are two other possibilities: constraining energy demand and switching to energy sources which produce less CO2. Apart from fiscal measures to reduce energy demand the main options are improved energy efficiency, increased uptake of nuclear and renewable energy sources (which make no net contribution to emissions) and increased use of gas in preference to coal.

A global switch to gas would have significant strategic, price and depletion implications. In the UK such a move would be unlikely to prevent emissions from rising but would slow them down. Renewable energy offers some scope in the longer term and the UK has a major R&D programme in this area. By 2030 renewables may help to constrain the likely rise in emissions in the UK and elsewhere but not offset it completely.

In the industrialised nations increased use of nuclear energy could make a useful contribution to meeting increased demand for electricity generation but would not reverse the upward trend of emissions. It seems doubtful whether developing economies could sustain a similar expansion of nuclear power. In the UK it can make little impact on CO2 emissions before 2000.

Improved energy efficiency in both supply and end use offers considerable scope in the near and long term. Some combined Heat and Power (CHP) schemes for example could achieve both simultaneously. From 2000 onward an improvement of 20% or more in end use efficiency may be available in the UK and possibly worldwide though not all of this would be translated into reduced emissions. The full potential is unlikely to be achieved on this timescale without significant market intervention both in the UK and worldwide

A decision to raise the priority to act on the climate change issue could have serious implications for energy policies in energy efficiency, coal, electricity, oil and gas, R&D and in international relations.

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CONTENTS

Note on energy units

1. Introduction

2. Carbon dioxide emissions

    2.1. Energy efficiency

    2.2 Nuclear power

    2.3 Renewable Sources

    2.4 Fossil fuel substitutions

    2.5 Implications for emissions

3. Methane

4. Tropospheric Ozone

5. Nitrous Oxide

Note on the units used below

The customary unit of electrical power is the Watt (W) as used in rating light bulbs. Large scale generation is usually expressed in units of a thousand million watts (10^9W.) or Gigawatts (GW) for short.

When electric power is used for some time it consumes an amount of energy measured in watt-hours or watt-years. For large energy use the customary units are a million million watt-hours (Terawatt hours or Twh for short) and a million million watt years (Terawatt years or TWy for short) Since these are measures of energy they can be used even when the energy is not electrical.

In discussing fossil fuels the customary and more easily envisaged unit of energy is the self-explanatory million tonnes of coal equivalent, abbreviated to Mtce. In energy terms Mtce is about 7.5 TWh.

Since the carbon in the fossil fuel becomes the carbon dioxide it is usual to describe potential or actual emissions of carbon dioxide in terms of the amount of carbon, usually in million tonnes of carbon or MtC. or thousand million tonnes of carbon, that is Gigatonnes of carbon (GtC).

1. INTRODUCTION

The climate change problem arises because the atmospheric concentrations of certain gases are rising and will lead to heating of the atmosphere. The chief culprits are carbon dioxide (CO2), chlorofluorocarbons (CFCs), Ozone (O3), methane (CH4) and nitrous oxide (N2O). The magnitude of heating and its consequences for climate are not well understood yet and are discussed elsewhere in this paper. (Annex A)

The greenhouse gases which are energy related are CO2, CH4 and to a small extent O3 and N2O. CFCs appear in refrigerators and insulation materials but are discussed in a separate annex. CO2 plays by far the greatest role and most of this annex is devoted to it.

2. CARBON DIOXIDE EMISSION

CO2 is produced by both natural and man-made processes. Of the man-made emissions about 70-80% come from burning fossil fuels, that is coal, oil and natural gas. World reserves of fossil fuels have been estimated as in Table 1 which also gives 1986 usage.

TABLE 1 GLOBAL PRIMARY FOSSIL ENERGY

Source	Present Use		Reserves		Total Resources	
	TW	%	TWy	Gtce	TWy	Gtce
COAL	2.59	24	591	636	9405	10127
OIL	4.24	41	125	88	365	257
GAS	1.61	17	76	64*	333	280*
TAR SAND/SHALE	0	0	99	70		
TOTAL	8.44	82	891			

Source : Keepin et al 1986 * million million cubic metres

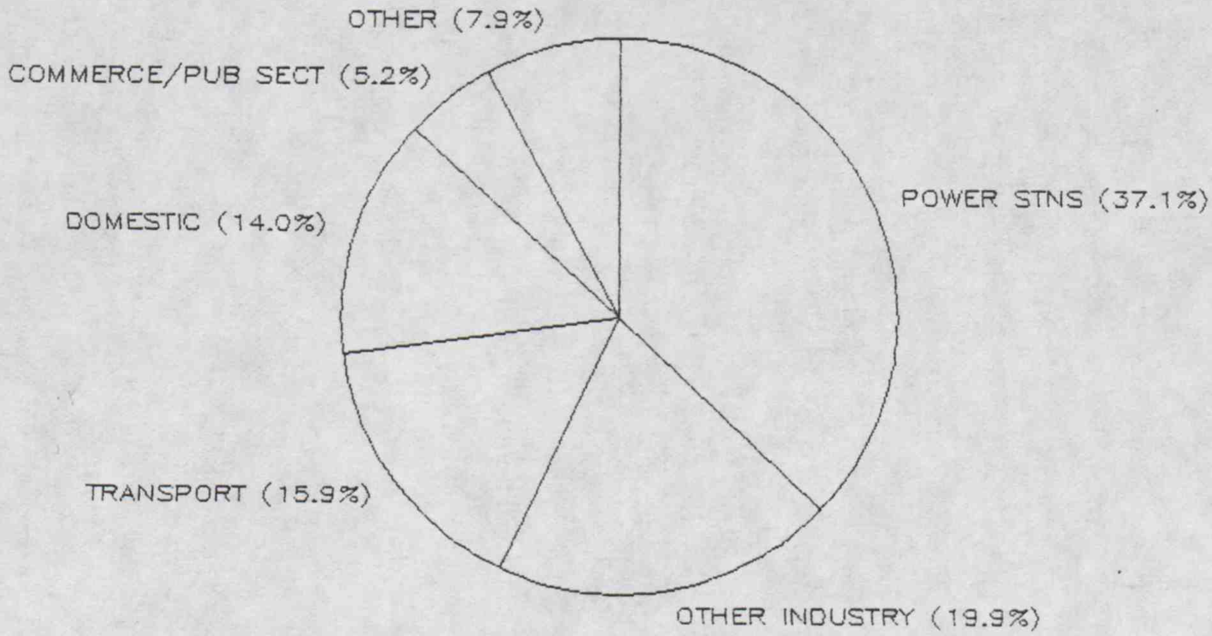
This shows that coal resources are much larger than oil or gas and that actual reserve levels will not constrain use of fossil fuels for some decades. CO2 emissions rise, of course, with increased fuel use but not all fossil fuels contribute equally. For each unit of energy, oil releases about 82% of the CO2 produced by coal, and gas about 57%.

Emissions of CO2 for the UK and the world are as follows. The UK situation in 1987 is shown in Tables 2,3 and in figure 1 and the trend till 1987 in Table 4.

FIGURE I

UK CARBON DIOXIDE EMISSIONS 1987

TOTAL 171.1 MILLION TONNES C AS CO2



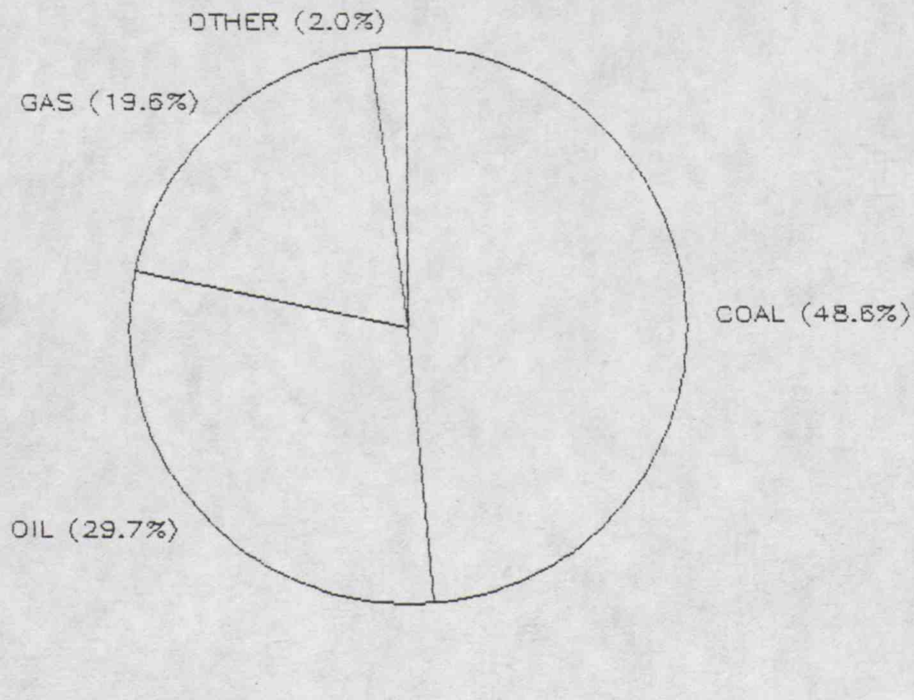


TABLE 2 UK CARBON DIOXIDE EMISSIONS 1987

SECTOR	M TONNES CARBON	%
COAL	72.6	42
SOLID SMOKELESS FUELS	9.6	6
COAL DERIVED GASES	0.9	1
COAL SUB TOTAL	83.2	49
PETROL	19.4	11
DERV	7.2	4
GAS OIL	6.5	4
FUEL OIL	7.9	5
REFINERY FUEL	4.2	2
BURNING OIL	1.8	1
OIL DERIVED GASES	4.0	2
OIL SUB TOTAL	50.9	30
NATURAL GAS	29.9	18
GAS PRODUCTION	2.2	1
GAS FLARING	1.4	1
GAS SUB TOTAL	33.5	20
FOSSIL FUEL SUB TOTAL	167.6	98
OTHER SOURCES	3.6	2
TOTAL ALL SOURCES	171.1	100

Source WSL

TABLE 3 UK CARBON DIOXIDE EMISSIONS 1987

SECTOR	M TONNES CARBON	%
POWER STATIONS	63.4	37
OTHER INDUSTRY	34.1	20
ROAD TRANSPORT	26.6	16
DOMESTIC	23.9	14
COMMERCE/PUBLIC SECTOR	8.9	5
REFINERIES	5.8	3
AGRICULTURE	0.7	1
RAILWAYS	0.6	1
GAS PRODUCTION	2.2	1
CEMENT MANUFACTURE	1.9	1
INCINERATION	1.7	1
GAS FLARING	1.4	1
TOTAL	171.1	100

Source: WSL

TABLE 4 UK CARBON DIOXIDE EMISSION TRENDS 1977 - 1987

YEAR	1977	78	79	80	81	82	83	84	85	86	87
M TONNES CARBON	178	180	190	173	167	163	161	153	164	169	171

Source: WSL

Similar data for the world as a whole are given in Tables 5 and 6, but only for earlier years.

TABLE 5 WORLD CARBON DIOXIDE EMISSIONS (Mt C as CO_2)

	1983	%	1984	%	1985	%
COAL	1993	36	2080	36	2182	37
OIL	2172	39	2218	38	2197	37
GAS	733	13	786	14	807	14
FLARED GAS	52	1	52	1	52	1
ALL FOSSIL FUELS	4950	89	5136	89	5238	89
WOOD FUEL	505	9	510	9	512	9
CEMENT MANUFACTURE	125	2	132	2	134	2
TOTAL	5580	100	5778	100	5884	100

Source: Rotty, 1987.

TABLE 6

ESTIMATED WORLD CO_2 EMMISSIONS FROM FOSSIL FUELS 1982 (Mt C as CO_2)

COUNTRY	EMISSION	% WORLD TOTAL
USA	1135	24
USSR	901	19
CHINA	413	9
JAPAN	226	5
FRG	181	4
UK	141	3
POLAND	112	2
FRANCE	110	2
CANADA	108	2
INDIA	105	2
ITALY	88	2
GDR	83	2
MEXICO	74	2
S AFRICA	67	1
CZECHOSLAVAKIA	64	1
AUSTRALIA	58	1
SPAIN	54	1
ROMANIA	51	1
BRAZIL	42	1
NETHERLANDS	36	1
BELGIUM	29	1
OTHERS	669	14
TOTAL	4747	100

Source: Rotty, 1987.

Forward projections under a range of scenarios are shown in Figures 2,3 and in Tables 7, 8 for the UK and World respectively. The three scenarios for the UK assume no special steps are taken to abate CO2 and are distinguished by the assumption of high (3.25%), central (2.25%) and low (1.25%) growth rates of G.D.P. They also

FIGURE 2

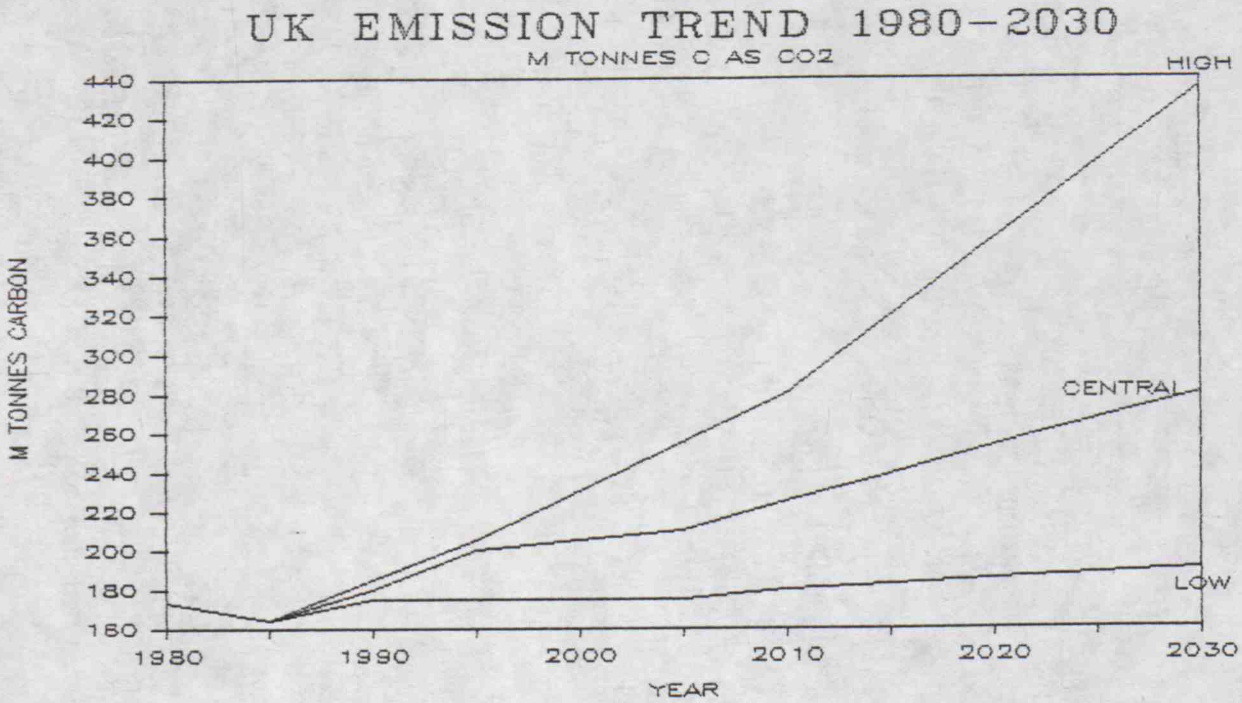
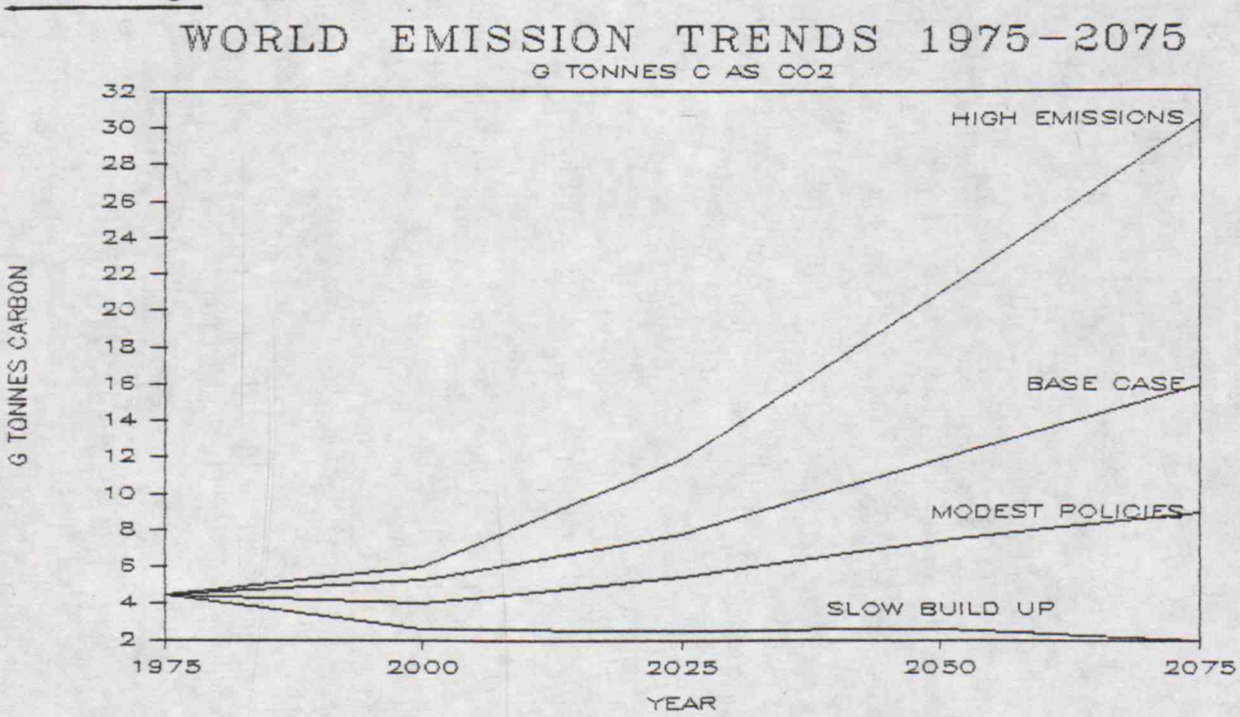


FIGURE 3



each contain an implied breakdown of energy use and supply, for example, electricity generating capacity into coal, gas, nuclear and renewables and a measure of energy efficiency achieved. As the position of the non-fossil fuel obligation is unclear after 2000 it has not been used as a constraint in the scenario. The central case of Figure 2 produces by 2030 a mix of generating capacity of 25% coal, 4% renewables, the Sizewell + 3 family of nuclear reactors (another 4%) and a massive switch to gas fired generation. Since this scenario assumes relatively modest increases in fossil fuel prices, there is only a modest uptake of energy efficiency measures driven by market forces alone.

TABLE 7

ESTIMATED UK CARBON DIOXIDE EMISSION SCENARIOS 1977-2030

	YEAR	1977	1980	1985	1990	1995	2000	2005	2010	2030
M	HIGH				185	205	230	255	280	435
TONNES	CENTRAL	178	173	164	180	200	205	210	225	280
CARBON	LOW				175	175	175	175	180	190

TABLE 8

RANGE OF PROJECTED WORLD CO2 EMISSIONS FROM FOSSIL FUELS

Gt C as CO2	1975	2000	2025	2050	2075
HIGH EMISSIONS	4.5	6.0	12.0	21.0	30.5
BASE CASE	4.5	5.3	7.8	12.0	16.0
MODEST POLICIES	4.5	4.0	5.5	7.5	9.0
SLOW BUILD UP	4.5	2.6	2.5	2.6	2.0

Soure: WRI (Mintzer). A Matter of Degrees

The four world scenarios are on a slightly different basis. The high and base cases assume no policies on CO2 and represent two assumptions on per capita energy use. The modest policies line refers to policies designed to reduce CO2 emissions and the low case strong global efforts to do this.

These Tables indicate that while in the UK there was a fall in CO2 emissions during the early 1980's they are expected to rise again unless further action is taken. For the world as a whole the expectation is that the substantial rises of recent years will continue unless steps are taken.

Once CO2 is in the atmosphere there are no large-scale man-made means of removing it except by growing biomass. Much of this is just a temporary store of carbon but longer term reforestation has been suggested as a contribution to lowering CO2 concentrations. It is discussed in Annex E.

Reduction of CO2 emissions by cleaning up flue gas has been assessed. It is technically feasible on a small scale. It has been estimated that applied to large electrical generation plant it would more than double the capital costs and lower the efficiency by up to 20%. It would be very difficult to apply to disaggregated small plant or motor cars. It would give rise to an enormous CO_2 disposal problem with the oceans being the likely repository. Nonetheless, it would be worth examining this possibility in more detail.

The conclusion we are driven to is that emissions have to be reduced if CO_2 levels are to be stabilised. This can be done either by reducing overall fuel demand, that is by energy efficiency measures in both supply and end-use, or by switching to fuels or sources with lower or zero CO_2 emissions. The options are nuclear power, renewable energy sources or fuel switching as in gas for coal. The possibilities for the transport sector are discussed in Annex F; the industrial and domestic energy sectors follow.

2.1 ENERGY EFFICIENCY

2.1.1 EXISTING PROGRAMMES

The work of the Energy Efficiency Office is aimed at overcoming market barriers to improved energy efficiency, primarily by the provision of advice and information. General awareness of the importance of energy efficiency has increased in recent years and the emphasis is now on providing more targeted advice. Much of our activity is in the industrial sector, where energy use is highly concentrated and directly relevant advice can be given to individual consumers.

The main existing programmes are:

INDUSTRY AND COMMERCE

Energy Efficiency Demonstration Scheme

Provides grants to host companies to demonstrate new and improved technology, designs and building measures, and new applications of existing technology which enable energy to be used more efficiently. Savings of over £190 million a year being achieved. Cost about £7 million per annum. Due to end (i.e take no new projects) 31 March 1989.

Research and Development Scheme

R&D support to encourage innovation in energy efficient technology in industrial plant and operations, and in buildings. Cost to EEO about £3.4 million this year, but due to decline.

Monitoring and Targetting

Promotes energy management by helping sectoral bodies to develop and promote energy management ("monitoring and targeting") system in major sectors of industry and commerce. Savings of £75 - 100 million a year being made through this programme. Cost to the EEO about £2 million this year; due to decline to zero in 1991/92.

DOMESTIC SECTOR

Community Insulation Projects

Install free or low cost draught-proofing and (sometimes) insulation, and provide energy advice, to low income households. The labour comes from people on Employment Training. Cost to the EEO about £1 million a year in grants. In addition DSS contribute about £9 million p.a. in payments for materials, and the Community Programme labour costs are about £35 million a year. Over 500,000 low-income households have been treated under scheme so far.

Home Insulation Scheme

This is operated by DOE, Scottish and Welsh offices. It encourages insulation of lofts by offering grants (now restricted to low income consumers). Over 3 million grants have been paid since 1978. Spend is about £22 million p.a.

OTHER PROGRAMMES

The EEO also undertakes the following activities:

Promotions

EEO's promotional activities aimed at publicising and encouraging energy efficiency. Targets now carefully identified e.g. high energy users in industry. Current EEO expenditure about £5 million a year; due to decline.

Combined Heat and Power (CHP)

Our objective is to provide a level playing field for CHP compared with conventional generation. Power generation is the largest single source of CO_2 emissions in this country; a shift from conventional coal-fired generation to combined cycle gas turbine CHP reduces CO_2 emissions by about three quarters if the discharged heat can be used.

Public Sector

Research, political pressure, and work to overcome institutional barriers comprise our main activities to promote energy efficiency in the public sector. Of course prime responsibility rests with the energy users, not the EEO.

NEW SCHEME

The EEO is currently working on a new scheme. Its aims will be to spread "best practice" in the use of new and existing technologies and practices, management techniques, design methods and contractual relationships between consumers and others (e.g. energy management companies): to advance "best practice", and get the results used; and to provide proven energy use yardsticks and get people to compare their energy use with those yardsticks.

INTERNATIONAL INITIATIVES

At the international level the EEO is a particpant in agreed energy efficiency initiatives. The UK is committed to the EEC's aim of improving energy efficiency by 20% by 1995 as part of Community-wide energy objectives. We have also accepted - for instance in response to the Bruntland Report - that cost effective measures to promote energy effficiency must be encouraged in the promotion of sustainable development.

2.1.2 POSSIBLE FUTURE ACTION

The measures open to the Government fall into four main categories: Advice and Information; Support for RD&D; Regulation; and Subsidies for Energy Efficiency Measures. The activities of the Energy Efficiency Office at present, as listed above, fall largely into the first two of these categories. Regulation and Subsidies are used only where there are specific market barriers which can not easily be overcome in other ways. It would, however, be possible to step up the rate of our activity in all of these areas.

Looking first at providing advice and information; much of our work at present is in the industrial sector, which is highly concentrated in terms of its energy use. With more manpower, we could increase the amount of specific and targeted advice given to these major users. With more resources, we could expand the advice and information services more generally. At present we do not give site-specific advice - this was formerly done under the Energy Efficiency Survey Scheme (which was terminated in June 1988). It would be possible to introduce a new scheme giving this sort of specific information.

We could relatively easily increase the rate of spend on general advertising in the press and on television, and so reach large numbers of consumers; but it is difficult to establish the cost-effectiveness of such a measure. It will be seen from Tables 9,10 & 11 that the buildings sector (commercial, public and domestic) is a key market (about 50% of energy use), and the savings potential is large. But is unlikely that advice and information alone will have much impact on this sector.

PATTERNS OF ENERGY USE AND SCOPE FOR SAVINGS IN UK

TABLE 9 - INDUSTRY

	Energy Use PJ/YEAR	Energy Use £M	Scope for Savings PJ/YEAR	Scope for Savings £M
Metal Manufacturing	334	1,493	89	367
Ceramics	214	887	50	207
Chemical	324	1,276	69	220
Paper, Printing, Stationery	135	520	26	58
Food, Drink, Tobaco	176	538	35	78
Engineering	304	1,293	43	208
Textiles, Leather, Clothing	120	461	20	48
TOTAL	1,607	6,453	332	1,186

TABLE 10 - DOMESTIC SECTOR

	PJ/YEAR	£M	Scope for Savings PJ/YEAR	Scope for Savings £M
Electricity	310	4,545)		
Gas	1,021	3,727)		
Oil	103	292)		
Solid Fuel	320	1,213)		
TOTAL	1,762	9,777	862	4,120

TABLE 11 - SERVICE SECTOR

	PJ/YEAR	£M	Scope for Savings PJ/YEAR	Scope for Savings £M
COMMERCIAL:				
Offices, Distribution	148	915)		
Shops	70	558)		
Catering, Pubs/Clubs	61	433)		
Residential	54	380)		
Retail Services and Other	55	383)		
SUB TOTAL	388	2,669	150-210	1,085
PUBLIC:				
Coastal Government	41	216)		
Defence	33	139)		
Local Government	76	302)		
Education	111	415)		
Health	104	409)		
Street Lighting	8	92)		
SUB TOTAL	373	1,573	160-230	725
SERVICE SECTOR TOTAL	751	4,242	310-440	1,810

<u>RD&D</u> It is clear that further research is needed into the implications of the greenhouse effect for energy production and energy efficiency, and the Department is already undertaking work in this area. As a means of promoting energy efficiency, however, there is probably not a very strong case for a major expansion of our present and planned efforts. The key finding to come out of many energy efficiency research studies is that a very large part of the savings potential arises from the application of existing technology, rather than from the introduction of new technology. The new technology is however more attractive to consumers, and often basic measures only get introduced on the back of new technology.

<u>Regulation</u> We already see a role for regulation where there are specific market barriers - in the buildings sector, the landlord/tenant relationship, and the nature of the housing market justify an energy efficiency component in buildings regulations - this is discussed in more detail below. There are potentially other areas where an emphasis on regulation could help support a market-based approach.

In addition, there are a number of areas where a regulatory approach or a strengthening of existing regulation could reinforce our activities without distorting commercial incentives:

- We have been considering the possibility of an obligation on the privatised electricity industry to provide energy efficiency measures on a commercial basis for the homes of low income people.

- A strengthening of buildings regulations is currently under consideration.

- The possibility of regulations and standards requiring better information about, and better levels of, appliance efficiency could be considered.

<u>Subsidies</u> At present, our only direct subsidies for energy efficiency measures are those which apply to people on low incomes. Subsidies can produce a greatly enhanced take-up of energy efficiency measures, and could be consistent with recognition that energy efficiency resources would counter an economic externality; but any major extension of subsidy would be inconsistent with present Government policy that energy users should not be subsidised for doing what is in their own interests.

<u>Barriers</u>

The need for Government action has to be considered in relation to the institutional and other barriers which impede the achievement of energy saving. An important barrier in the industrial and commercial sectors, as noted above, is lack of information, and that is where our main activities lie. There are two further main barriers in the buildings sector:

i. The landlord\tenant relationship In the complex buildings market, this leads to a situation where neither landlord nor tenant has a proper incentive to invest in energy efficiency. We can act on this directly through buildings regulations, and through encouragement and the provision of advice and information. If energy costs were included as a fixed item in rents, the incentive on the landlord to increase the energy efficiency of the property would be much increased.

ii. Public Sector There appears to be very significant scope for savings across many parts of the public sector, which is a major occupier of buildings. Despite the mechanisms for control of expenditure, normal commercial incentives are blunted. Specific barriers include a failure to invest sufficiently - caused both by the impact of cash limits, and by the tendency of public sector managers to prefer their own operational priorities (e.g. pressure to invest in a new operating theatre rather than a new heating system). The incentive to invest in order to achieve savings is often weak because public sector managers fear they will not be able to retain any savings achieved. Possible Government actions include top level interest in promotion of energy savings; relaxation of the cash limits approach to allow savings to be retained; and in particular, more flexible rules and greater will on the introduction of private capital and expertise. Action by Government is important not only because of its size as a consumer of energy, but also because it must be seen to be in the lead, and practicing what it preaches.

Finally, given the importance of electricity generation in the greenhouse effect, it would be possible in principle to put more emphasis on promoting electricity savings in particular. At present, our programmes do not necessarily have this effect - for instance, the better insulated a building, the more likely it is to be economic to use electricity to heat it. We are looking at the implications for our programmes of such a concentration on measures likely to lead to a reduction in CO_2 emissions.

2.1.3 OVERALL SAVINGS

The above discussion and Tables range over a number of very disparate market sectors (excluding transport). The figures in the Tables should be taken as upper limits. The major scope for savings lies in the buildings sector and this indicates that they cannot be realised over a few years, given the slow rate of refurbishment and new build.

There are difficulties in translating this multitude of numbers into fuel savings and hence reduced CO2 emissions. For example, a reduction in specific energy need of a process may allow enhanced production and no overall energy saving. Similarly improved efficiency in the domestic sector is often taken in comfort. The Energy Efficiency Office estimates that from about year 2000 onwards we could have an overall 20% improvement over what would happen if no futher energy efficiency measures were introduced.

The difficulties in estimating are greatly compounded when we look at the world as a whole. Our best advice at present is that the overall 20% is still a reasonable estimate. It is consistent with the 1%-1.5%pa used in the modest and low scenarios of figure 3

2.2 NUCLEAR POWER

2.2.1. PRESENT UK POSITION

The present nuclear capacity in the UK comprises 6.5 GW of plant in full commercial operation with a further 3 GW in the final stages of commissioning. Last year, 45 TWh of electricity was generated by nuclear stations, which is 16% of total electricity production.

The output last year was depressed by poor performance from the AGR stations. The output from these stations is expected to increase and, with the addition of two new AGRs (Heysham B and Torness), the nuclear component is expected to increase over the next few years to 63 TWh or 20% of the total electricity generation. About 13 TWh of output would be added to these levels if the electricity from France is assumed to be nuclear.

For comparison, the table 12 shows the level of nuclear capacity in the OECD countries.

TABLE 12 NUCLEAR CAPACITY IN OECD COUNTRIES

OECD area & country	CAPACITY GW(net)	%
Europe	108	
France	50	51
West Germany	19	20
UK	10	15
Spain	7	16
Sweden	10	29
Belgium	6	39
Other countries	7	7
America	106	
USA	94	14
Canada	12	12
Pacific	26	
Japan	26	17
TOTAL	240	

2.2.2 PROSPECTS FOR THE MEDIUM TERM

During the 1990s, based on current plans, four Pressurized Water Reactors (PWRs) will be built and commissioned in the UK providing up to 5GW of capacity and 33TWh of output. However, by the time these new plants come on line, all but one of Magnox stations should have reached the end of their planned life and thus, unless life extended, be closed with a loss of about 23 TWh of output. This means that probably there will only be a small increase in nuclear generation by the year 2000.

Given the long planning and construction time for nuclear plant, it is unlikely that significant further additions to nuclear capacity could be achieved by the year 2000, perhaps one extra station of 1.2GW is the best that could be expected. An additional cross channel link with France is also a possibility subject to supplies being available.

If the current nuclear power in the UK had to be replaced by coal based generation carbon production would increase by 15 million tonnes (24%), or rather less if a mixture of coal and oil generation was used.

2.2.3 LONG TERM OUTLOOK

In a CEGB published scenario by the year 2030 about 100GW of installed generating capacity will be needed to meet UK demand for electricity. This estimate lies between the two lower cases of Figure 2. This represents an increase of 30 GW over the present system capacity or a growth in demand of just over 1% per annum. Between 2000 and 2030, most of the generating plant currently in service or planned will have to be replaced or, undergo major refurbishment. This means that 3.3 GW p.a. of "new" capacity (the equivalent of two 1800MW coal stations or three PWRs) each year will have to be provided over the period.

As an example, consider three possible options for providing generating capacity for the year 2030 and their effect on carbon production.

-If the new capacity,(95 GW of the 100GW total), is all coal fired plant, i.e. there is no new nuclear plant to replace that which reaches the end of life and renewables make no contribution, then carbon production will be 164 million tonnes p.a., or over $2^1/_2$ times the 1987 levels.

-If the current proportion of nuclear (or non-fossil) generation remains as expected when the AGRs are fully commissioned ie 20% then carbon production will be $2^1/_4$ times the 1987 levels. This implies a construction rate of 0.4GW/p.a. for nuclear plant or a new PWR every three years.

-If the maximum use is made of nuclear power limited only by a construction rate for new plant of say 1.5 GW/yr, then by the year 2030, 45 GW of additional nuclear capacity will be available which will limit carbon production to 83 million tonnes p.a., i.e. an increase of 30% over 1987 levels.

This upper level is considerably higher than has previously been achieved in the UK, but is a lower build rate than achieved in France, where nearly 50 GW of nuclear capacity has been installed over the past 15 years or so. The level of carbon production also depends on the level of demand and the figures below for the UK capacity are based on those used by the CEGB in their evidence to the Hinkley C Inquiry, which include an allowance for a "natural" increase in end-use efficiency.

2.2.4 INTERNATIONAL POSITION

The table above giving nuclear capacity of OECD countries indicates that all countries except France could increase nuclear generation substantially by 2030. The prospects are less clear for the developing countries because there must be doubts about whether their technical infrastructure would be capable of handling nuclear power. The concept of small replaceable nuclear reactors which do not have to be refuelled may help ease this constraint, but these have not yet been developed.

Nuclear generation can only displace fossil energy in electricity production and there are no plans for using nuclear energy for other purposes. This places an upper limit on the contribution nuclear power could make to reducing the greenhouse effect, even though electricity is expected to increase its share of the market.

If all OECD countries embarked on a high enough nuclear policy, the price of uranium can be expected to rise sharply. In such a scenario, the Fast Reactor becomes important sooner than now expected, possibly sometime between 2010 and 2030, because of its ability to produce additional fissile material for thermal reactors. Continuing access to the development of this technology would be desirable for this reason. Fusion is not expected to be available as an option before 2050, which is probably too late to form part of the response to counteract the greenhouse effect though the climatic threat may strenghthen its claim as a longstop insurance technology.

2.3. RENEWABLES

2.3.1 UK EXISTING PROGRAMME

Only limited use is made of renewable energy at the present time in the United Kingdom. Hydro electricity provides about 1.5% of electricity generated or a little over 0.5% of total consumption of all fuels. There are no statistics for other renewable sources. However, it is probable that rural use of wood and combustion of forestry, industrial, agricultural and domestic wastes provides between 1 and 2 million tons coal equivalent, say, 0.5% of the total energy consumption.

For the future, the position is uncertain since many of the renewable technologies have not been developed yet to a state where the performance, costs and environmental implications can be predicted with any certainty. The Department has, however, been pursuing a programme of research, development and demonstration on renewable energy since the mid-1970's in order to:

- Stimulate the full economic exploitation of alternative energy sources in the UK;
- Establish and develop options for the future;
- Encourage UK industry to develop capabilities for the domestic export markets.

The programme aims are to:

- Phase 1: Identify and assess appropriate technologies between the mid-70's and mid-80's;
- Phase 2: Develop, in collaboration with industry, those technologies with commercial prospects between the mid-80's and early 90's;
- Phase 3: Demonstrate those technologies, transfer the technical knowledge to the manufacturing industry and potential users, and where appropriate transfer the responsibility for further development to them by the turn of the century.

Almost all technologies require greater and greater expenditure as they move from paper assessment through the small-scale practical work to full-scale field trial and demonstration. Development of renewable energy is following this pattern. As commercial prospects and markets are identified, industrial involvement in funding will need to increase until the point is reached where industry takes full responsibility for commercial development and deployment. Current expenditure is around £20 million per year of which £16 million is provided by the Department of Energy. By the mid-90's, if all promising technologies are taken to the point of commercial exploitation, then expenditure will need to rise to around £70 million per year of which an industrial share would need to be about two-thirds. It is assumed that industry will have taken over totally by the year 2000.

2.3.2 UK PROSPECTS

It appears likely that renewable energy sources could make a useful and economic contribution to the UK economy beginning in the late 90's, thereby assisting the diversity of supply. They might also provide some insurance against long lasting unforeseen disturbances in energy supplies in the future. The direct electricity producers such as hydro and wind do not of course produce carbon dioxide. Those involving the combustion of biomass such as forest wastes, refuse or landfill gas do but carbon can be recycled assuming that biomass is replanted.

The table below show estimates of the possible contribution from renewables in the UK by the year 2025, at costs competitive with conventional options, and also the technical potential which is available ultimately though possibly not within today's economic or environmental constraints.

TABLE 13

TECHNICAL POTENTIAL AND ESTIMATED CONTRIBUTION FROM RENEWABLES IN THE UK BY 2025

Electricity Producers

Technology	Technical Potential (TWh/year)	Estimated Contribution(2025) (TWh/year)
Wind Power		
Onshore	45	0-30
Offshore	140	?
Tidal	54	0-28
Geothermal HDR	210	0-10
Wave	50	0-0.2
Small-Scale Hydro	2	0.3-0.7
Heat Producers	(MTCE/Year)	(MTCE/Year)
Passive Solar	8-14	1-4
Biofuels		
Wet and Dry Wastes (includes Landfill Gas)	22	3-10
Forestry	At least 20	1-5

Assuming the planned R & D is reasonably successful and there are no major disturbances from current trends, then perhaps half the maximum estimated contribution for the year 2025 might be exploited. This would amount to about 30 TWh/year of direct electricity producing renewables and 8 million tons coal equivalent from combustion of fuels.

If there are pressures, such as environmental considerations, to exploit more renewable energy then perhaps it would be possible to exploit the full 70 TWh/year from direct electricity producers and 15 mtce from combustion for fuels. This would however assume complete success in R & D and construction of major projects such as the Severn Barrage which itself could account for around 14 TWh/year electricity.

The above estimates all assume that developments are not required which would disturb a conventional economic framework severely. If major costs were found to be incurred by, for example, the need to severely restrict carbon dioxide emissions, then a further proportion of the very large technical potential might be exploited but at significantly higher cost than under conventional assumptions.

2.3.3 CURRENT WORLD ACTIVITY

Renewable energy also contributes on only a modest scale to total world energy supplies as far as "commercial" use of fuel is concerned. Approximately 7% is estimated to come from renewables split equally between hydro sources and biomass. There is however extensive "non-commercial" use of biomass with wood and agricultural wastes providing for the majority of fuel in rural use in developing countries. This is of course a small amount in total but no reliable statistics are available.

Most industrialised countries have renewable energy research programmes, similar in nature to the UK. The use of renewables is primarily determined by geographical and climatic factors with, for example, solar and wind being applicable in different zones.

2.3.4 WORLDWIDE PROSPECTS

The WRI scenarios predict the following world energy usage for the year 2025.

TABLE 14 World Energy Supply 2025

Scenario	Total Energy (TWy)	Renewables: Direct Electricity %	Renewables: Fuel (Biomass) %
Base Case	16.6	20.1	4.2
High Emissions	22.7	14.7	3.0
Modest Policies	13.4	24.3	5.6
Slow Build-up	8.0	22.3	14.4

Source WRI

The proportion of renewables projected for the remainder of the world is somewhat larger than for the UK predominantly because more extensive availability of hydro electricity. The Base Case, developing today's trends leads to approximately 20% of energy supplies coming from direct electricity producing sources, predominantly solar, and about 4% from Biomass. In a future where considerations of minimising carbon dioxide becomes predominant then their percentages increase to 26 and 14 respectively. It must be remembered however that the Biomass does not include 'non-commercial' use of wood and agricultural waste, which is likely to continue to increase wherever available timber and livestock will sustain it.

Overall increasing use of renewable energy sources could make a useful contribution to energy supplies and consequently reduce carbon dioxide emissions below what they would otherwise have been. They could not however, be more than one element in an overall programme to reduce emissions. Current plans should lead to the introduction of useful quantities of renewables. There would be considerable scope for increasing that quantity, however, if control of CO2 emissions becomes an important factor.

2.4 FOSSIL FUEL SUBSTITUTIONS

2.4.1 UK FUEL SWITCHING

All fossil fuels contain carbon and on their combustion release CO_2 however the energy available per unit of CO_2 released does vary between fuels. This is because they contain differing proportions of other combustible components - mainly hydrogen but also nitrogen and sulphur. The oxidation of these other components releases energy and produces waste gases other than CO_2 which are not considered to have equivalent greenhouse effects (of course the nitrogen and sulphur oxides procured are associated with the acid rain issue). Natural gas (methane) has the lowest proportional yield of carbon dioxide of any fossil fuel and the substitution of coal and oil by gas is one means to lower national CO_2 emissions (there is a secondary level of CO_2 saving which might be achieved because of differences in end use efficiency eg electricity plant operating on Gas may be intrinsically more efficient than that based on coal because different, more efficient technology is then possible).

If all the UK power station coal were to be substituted by gas then the resulting changes in CO_2 emissions would be:-

TABLE 15 EFFECT OF SWITCHING FROM COAL TO GAS FOR ELECTRICITY GENERATION (1987 UK FIGURES)

	EMISSION Mt C as CO2			GAS CONSUMPTION M THERMS		
	BEFORE	AFTER	%CHANGE	BEFORE	AFTER	%CHANGE
Electricity Gen	63.4	32.6	-49	75	20165	*
Other Sources	107.7	107.7	0	20699	20699	0
TOTAL	171.1	140.3	-18	20774	40864	+97

Such a substitution in the short term is entirely a hypothetical case as generating plant could not be built fast enough and new gas supplies could not be distributed and/or purchased on the international market in the volume required.

In the longer term major substitution could occur and some small moves in this direction are already mooted for the electricity supply industry post privatisation eg a number of gas fired electricity generating schemes are already proposed for early competition within the newly privatised industry. The European Directive limiting gas burn for electricity production is an obstacle in the path and the UK is attempting to have the directive quashed.

In other energy using sectors the ability to substitute is variable. In the domestic market gas generation is already high. In the commercial and public sectors the major competition would be for the space heating market and would be against oil (currently 40-50% market share). Gas already has about 35-40% of this market. Transport accounts for 16% of the CO_2 emissions and predominantly uses petroleum fuels. Substitution by natural gas (or methanol derived from natural gas) for petroleum could give some CO_2 emission benefits but this is dealt with in the Transport Annex F.

Any major switch into natural gas - alongside similar strategies adopted by other nations would severely impact the european and world gas markets. Worldwide known gas reserves are large $65x10^{12}m^3$ and give a reserve to annual use ratio of about 60. If consumption were to double then the current infrastructure could hardly cope and prices would rise rapidly.

2.4.2 HYDROGEN

The use of hydrogen as an alternative to fossil fuels particularly in the transport sector has long been championed. Its environmental case, particularly the total lack of CO_2 emissions during combustion, is strong. Unfortunately hydrogen is not itself a primary fuel and has to be produced by the use of other energy resources. If these are based on fossil fuel and there is an energy loss in the conversion process (as there is bound to be) then no abatement of CO_2 emissions can occur. If the production is based on non-fossil energy sources, eg nuclear, hydro, solar cells then the question becomes one of economics and competition with other secondary fuels eg electricity which can be made from such primary sources. As yet no sensible analysis of local production of hydrogen has shown advantage over electricity. The whole question of changing the energy infrastructure that hydrogen use would require is very problematical. Transport of hydrogen from distant cheap production sites may in the long term show some cost advantage but this is reliant on the development of vast hydro schemes (with their own environmental impact) or rapid advances in solar-hydrogen production technologies. Direct Biological production of hydrogen via a solar biochemical route is a long term possibility but must be discounted in the current analysis.

2.5 IMPLICATIONS FOR EMISSIONS

2.5.1 UK SITUATION

The sections above give impact on energy supply and demand of a range of options which are being pursued or could be pursued. In terms of their impact on CO_2 emissions we see that on a central case the UK emissions of CO_2 would rise from 171 Mtc in 1987 to 280 Mtc by 2030 unless remedial steps are taken. That central case included a low uptake of energy efficiency measures so a more vigorously pursued programme might give us up to 20% improvement. If we make the very optimistic assumption that this could all be taken as carbon savings, emissions in 2030 could be reduced by up to to 55 million tonnes.

In the central scenario, low fuel prices have given a nuclear component of 5GW, that is only 4 PWRs intended to help meet the non-fossil fuel obligation. A more rapid build of nuclear stations could lead to an upper limit of something like 50GW capacity by 2030. This would replace coal and gas burn and might reduce carbon emissions by about 60 Mtc.

Discussion of renewable energy contributions is complicated by the range of technologies and their different stages of development. We estimate that if present programmes are successful then by 2030 there could be a renewable contribution in the UK of about 23 Mtce. If pushed to the limits achievable within the expected economic framework this could possibly be doubled to around 50 Mtce. On its own this would be equivalent to saving up to 30 MTc per year.

Fossil fuel switching especially gas for coal would be likely to increase under the private sector ownership of electricity generation and is environmentally beneficial. However, the trends shown on figure 2 already take full account of this so we claim no further credit for it.

Finally, it would be inappropriate simply to add together these potential carbon savings. Not only have we taken upper limits for each - and therefore been extremely optimistic - but they are in effect competing with each other. In round numbers the maximum carbon savings from the energy sector (excluding transport) might be 75 Mtc per year.

2.5.2 WORLDWIDE

For the developed countries the options are broadly the same as for the UK and the impacts of the options are overall similar although clearly the detail will differ country to country. For the developing countries the way forward is much less clear and yet this aspect is vital. China for example is the third largest emitter of CO_2 at present and as shown in Table 16 has

TABLE 16 HARD COAL PRODUCTION IN CHINA

YEAR	Mte
1973	417
1978	593
1981	598
1982	641
1983	688
1984	759
1985	810
1986	840
1987	870

Source IEA

been increasing its coal production rapidly. If this were to continue it would make it vastly more difficult to achieve global reductions even with strong measures in developed countries. As Table 6 shows, the UK is the source of only 3% of world CO_2 emissions.

3. METHANE (CH_4)

Methane in the atmosphere is generated naturally by various biological processes and in some part by the energy related industries. Despite difficulties in estimating global production possibly more than half of the total is influenced by human activities. Table 17 summarises some estimates produced in the last few years for global production.

TABLE 17 GLOBAL METHANE EMISSIONS

Source	Million tonnes emission p.a
Rice fields and natural wetlands	50 - 230
Biomass burning	30 - 100
Domestic animals	70 - 80
Landfill gas from waste	30 - 70
Natural gas leakage	35
Coal mining	35
Insects and other natural fauna	35
Fossil fuel combustion	2
Other unknowns	?
TOTAL	250 - 525

The large uncertainty of the first two items accounts for the wide range of the estimate. Methane is known to be increasing in the atmosphere at just over 1% per annum. It is not clear if this is as a result of increased production or a slowing down of the natural destruction cycle in the atmosphere or both. The past increase in methane concentration correlates well with the increase in world human population.

The main energy related sources - leakage from the natural gas production and use system and from coal bed seepage account for only a minor proportion of the total (12-25%). The main production of non-useable methane from oil fields is flared - creating CO_2 but this is a preferable discharge to methane itself as it has a lower greenhouse potential. Obviously direct energy use of all methane production - be it from oilfields, coal beds or landfills (see section 2.3.2 renewables) would be beneficial both in terms of meeting energy demand thus replacing the need for a proportion of other fuels, and emitting CO_2 rather than methane. The practicability a major move in this direction is doubtful but some advances are already being made in the area of landfill gas utilisation. Increased use of natural gas as a substitute for other fossil fuels might increase the methane leakage rate but this should be only a minor reverse. There is little potential for the control of other methane sources.

4. TROPOSPHERIC OZONE (O3)

Stratospheric ozone (the upper atmosphere) is of extremely topical interest due to the great concern being expressed about its depletion and effect on all terrestrial life. It is not, however, the issue at hand. Tropospheric O3 - Ozone in the lower atmosphere, arises from the natural production cycle in the upper atmosphere and from photochemical processes in the lower atmosphere. There is little doubt that there is some increase of the gas but it is very difficult to assess the global change in concentration in the lower atmosphere as it varies widely between localities and regions.

The prime process of production of ozone in the lower atmosphere requires volatile organic species, nitrogen oxides(NOx) and sunlight. Volatile components of petroleum (VOCs), natural gas leakage and pollutant emissions from all combustion sources are thus implicated in the photochemical production. Natural emission sources of related chemicals are not well quantified but are possibly of equal consequence to the total anthropogenic emissions.

Moves to control nitrogen oxide emissions from both mobile and stationary sources will help limit ozone production as clearly would some energy efficiency measures. Deliberate release of petroleum and other volatile organic compounds in non-energy uses (eg aerosols, thinners in paint) accounting for some 40% of man made emissions in W. Europe is already being restricted in some countries. Control over evaporative losses from the petroleum and transport industries are being pursued in warm and sunny climates. Figures for Western Europe suggest that evaporative loses of VOCs from vehicles, refineries and the petroleum distribution system, correspond to only about 15% of the man-made emissions. Petrol vehicle exhausts account for about 25% of man-made emissions and control measures involving the use of either 3-way or oxidation catalysts on new vehicles will considerably reduce this source.

5. NITROUS OXIDE (N_2O)

Nitrous oxide is a natural constituent of the atmosphere and apart from the interest in its "greenhouse" effect it is intimately bound up with the stratospheric ozone destruction cycle. Nitrous oxide is chemically quite unreactive and has a very long residence time in the atmosphere. Quite small increases in its rate of production will thus have marked effect on its accumulated concentration in the atmosphere (currently at about 300 parts per billion). The table below gives some estimates by Bolle of the global sources of the gas.

TABLE 18 GLOBAL EMISSIONS OF NITROUS OXIDE

Source	Million tonnes per year as nitrogen
Natural soils	6
Agricultural fertilisers	0.6 - 2.3
Seas/oceans/fresh water	2
Biomass burning	1 - 2
Fossil fuel combustion	1.9 - 2.9
Cultivated land from deforestation	0.2 - 0.6
Lightening	0.1
TOTAL	12 - 16

Estimates suggest emissions are increasing at about 0.3% per annum while the accumulated concentration is increasing at about 0.2% per annum.

The nitrogen compounds which occur naturally in the fossil fuels on combustion are the source of the nitrous oxide. Fossil fuel combustion is one of the major human sources shown above but there is considerable uncertainty in the figure. Both fossil fuel burning and the use of nitrogen fertilisers have increased steadily over the last few decades.

One particular concern in the fossil fuel area is the possibility that moves to control nitrogen oxide (NOx) emissions from both mobile and stationary sources will increase the production of nitrous oxide. This is because the processes used attempt to reduce NOx to nitrogen and if the reaction is not carried far enough nitrous oxide may result. Both the catalytic and non catalytic processes are potentially involved. Recent measurement campaigns, trying to ascertain the extent of the problem, have shown variable results but there are suggestions that the problem is less than at first feared. As long as these results are confirmed there is little that the energy industries can further control in this area. NOx is by far the more important emission requiring control.

CONFIDENTIAL

ANNEX D

CLIMATIC CHANGE: IMPLICATIONS FOR TRANSPORT

Note by the Department of Transport

1. There are two main issues for transport:-

B) **The contribution transport makes to the greenhouse effect (GHE)**

B) **The impact of the GHE on transport.**

A. **CONTRIBUTION OF TRANSPORT ON GREENHOUSE EFFECT**

2. By far the most important impact of transport on the GHE is through emissions of CO_2. Other emissions, such as NOx, are far less important, though may act as a constraint on what can be done to reduce CO_2 emissions (see para 12 below).

3. Transport accounts for about one fifth of all UK CO_2 emissions. The vast bulk of this comes from road transport, with rail, shipping and air transport contributing less than 2% of the UK total. CO and H_2O are the products of perfect combustion of petroleum based fuels and will be present in quantities directly related to the amount of fuel consumed. This means any substantial reduction in CO_2 emissions from transport depends on reducing consumption of petroleum based fuels.

4. In 1987, road transport consumed some 22m tonnes of petrol and around 8m tonnes of derv. Consumption is dominated by cars and light vans, which together account for nearly all petrol consumption and about 7% of derv consumption. The remaining consumption of derv is accounted for roughly 80% by heavy goods vehicles and 12% by buses and coaches. As cars and light vans dominate fuel consumption, it is clear that any measure intended to reduce CO_2 must be substantially directed at this sector.

5. There are no regulations limiting CO_2 emissions from vehicles as such, though regulations do cover CO, hydrocarbons and NOx. Worldwide the emission of CO_2 has not been looked upon as 'pollution'; rather it has been considered as a benign product of efficient combustion, as opposed to CO which is the product of incomplete combustion.

6. All this suggests there are three main ways of limiting CO_2 emissions from transport. One is to seek an increased contribution from future vehicle design, including from vehicles being designed to use alternative non-petroleum fuels to service the existing pattern of transport (ie by keeping road transport at something like its present proportions of total transport). A second is to seek to influence driver behaviour and traffic patterns (eg congestion). A third is for the government to take specific action to intervene in the market to limit demand for petroleum-based transport fuels. These are discussed in turn below.

7. All three kinds of action need, however, to be seen against recent trends in the use of road transport. Over the 10 years since 1977 road transport consumption of petrol increased in the UK by approximately 28% and consumption of derv by nearly 50%. This substantial increase in consumption is associated with continuing economic growth and rising personal affluence. The proportion of households with regular use of cars is increasing (57% had one or more cars in 1977; and 64% in 1987; while households with two or more cars rose from 11% to 19% over the same period).

8. This upward trend is associated with changes in lifestyle and population distribution which has encouraged increased frequency in distance of car travel. Rising affluence is also associated with a long-term trend towards higher-performance cars with larger engines. While this trend was reversed in the immediate aftermath of the 1974 oil crisis, it rapidly resumed and is expected to continue in present market conditions.

9. The combined effect of all these trends has more than offset the very considerable improvements achieved in average vehicle fuel efficiency. Between 1978 and 1987 average car fuel consumption improved by about 20%.

FUTURE VEHICLE DESIGN

10. Broadly the same pattern of growth in vehicle usage more than offsetting improvements on fuel economy is expected to continue in the future as in the past. The National Traffic forecasts for Great Britain show increases of 23% (low growth) and 47% (high growth) in vehicle kilometres form 1986 to 2010. So despite likely improvements in vehicle design, barring a major upheaval in the international oil market, consumption of fuel by road transport seems virtually certain to go on increasing as far

ahead as can be foreseen. Only partly offsetting this, a further 30% improvement in average car fuel consumption efficiency is possible by 2010 by changes to the internal combustion engine, transmission and other aspects of car design.

11. There are at least two additional factors, however, (apart from growth in vehicle usage) which may prevent this inherent further improvement from being achieved. The first is that these improvements can be and have been offset by changes in the expectation of the user. At present manufacturers consider good fuel economy to be a significant selling point and therefore can be expected to pursue the further improvements mentioned. But much will depend on the customer's willingness to accept change, for example the extensive use of constant velocity automatic transmissions.

12. Second, virtually any action to control CO, hydrocarbons and NOx from vehicle exhausts, which has been the case in the UK since the early 1970s, has an adverse effect on fuel economy compared with what would otherwise be the case. The present government policy to apply limits recently agreed in the EC (the 'Luxembourg limits') in the 1990s will, it is estimated, produce an increase in fuel consumption of 2% - 5% higher than would otherwise be the case. On a European Community level the move towards 3-way catalyst technology will exacerbate the fuel consumption penalties associated with emission controls. If the EC adopt emission levels which require the use of 3-way catalysts on all cars (at present these are only required on large cars) then a further 5% to 10% deterioration can be expected in fuel economy in the later 1990s. The UK's stance in previous discussions on pollution from motor vehicles has been to emphasise the importance of taking energy saving into account. The emergence of the greenhouse effect as an important environmental issue adds further justification to our support for lean-burn engine technology, which does not require the use of 3-way catalysts. Lean burn technology was developed primarily as a fuel saving measure, though with important spin-off benefits to emissions. The possibility arises of re-stating the fuel economy benefits of this technology when Community limits are reviewed in 1991.

ALTERNATIVE FUELS

13. In the short term fuels suited to the internal combustion engine appear the most probable alternatives to present-day fuels.

14. To make a radical reduction in CO_2 emissions would require a shift to fuel other than the hydrocarbon fuels used today (petrol and diesel). But at present none of the possibilities look very promising. Hydrogen would produce no CO emissions and could be used as a fuel for the conventional internal combustion engine. But the development of suitable engines and fuelling systems is very much at the experimental stage. The production of hydrogen is energy fuelling intensive, and this and distributing and storing the fuel safely would need to be taken into account. Another theoretical possibility is the use of menthanol; however when the energy content of the fuel is taken into account the reduction in CO_2 emissions may not be significant. Compressed natural gas (CNG) is yet another option; but it does not look an attractive economic possibility especially in countries such as the UK where it is not naturally available.

15. Electricity, if supplied from non-fossil fuelled power stations, could be used for some transport needs. Much wider use of electric vehicles would require a major modification to user patterns or a break-through in electricity storage technology.

DRIVER BEHAVIOUR - TRAFFIC CONGESTION

16. How vehicles are driven can make an appreciable difference to the amount of fuel used. It is estimated that driving habits of the user can vary fuel consumption by 25% between the worst and the best driving practices. Action to bring the standards of the worst up to the best is, however, very difficult.

17. Another factor that can affect fuel consumption is congestion. Avoiding stopping and starting can improve fuel consumption - though against this more roads to relieve congestion can encourage more journeys. In London - perhaps the most difficult area - substantial investment in public transport is already planned.

18. More generally traffic restraint has been practised only on a limited basis, either in the form of local restrictions (pedestrian streets, lorry bans etc) or by controlling the availability of parking. Schemes which merely displace traffic from one street to another do not affect the global production of emissions and may even increase it if the result is greater congestion elsewhere, longer mileage for a given journey or both. Restrictions on parking are an effective restraint mechanism only if they

are rigorously enforced and cover a sufficiently wide area to forestall a displacement effect. Effective parking enforcement benefits traffic flow in two ways, firstly by reducing the congestion caused by illegal parking and secondly by deterring some motorists from driving into the affected area at all.

MORE RADICAL MEASURES TO REDUCE DEMAND

19. Arguably only measures to limit demand substantially would be sufficient radically to reduce CO emissions, at least in the short to medium term (ie pending any radical changes in vehicle design). Direct controls over vehicle ownership and use (eg banning second car ownership or prohibiting the sale of vehicles with large capacity engines) are likely to be difficult from both the political and the enforcement point of view. Measures which in principle could help to reduce demand include:-

a) More draconian restrictions on parking or on access to certain parts of the country;

b) Very substantial addditional investment in public transport capacity;

c) Government intervention in the pricing mechanism, which in turn could be achieved by:-

   i an active fiscal policy to encourage the greater use of public as opposed to private transport, or more fuel efficient vehicles, eg through fuel excise duty, vehicle excise duty, car taxation or taxation of company cars;

   ii charging mechanisms, such as road pricing arrangements or parking charges (to make a major impact these would have to be sufficiently comprehensive to avoid simply displacing traffic from one area to another).

20. Such proposals, are however areas which have been looked at fairly extensively by Ministers over recent years, though not specifically in relation to climatic change. The

essential question is whether the impact of transport on climatic change is expected to be sufficiently severe as to justify re-examining or reversing policies in these areas.

21. Such policies would not of course have a significant effect on the climate unless they were accompanied by corresponding action by much of the rest of the developed world. European collaboration would be the minimum necessary to achieve any significant improvement (and leading the way to such collaboration might provide scope for new UK industries to exploit new opportunities). But a substantial impact would require the collaboration of the USA. This might not be easy in view of the very low price of fuel there. In a sense what would be required would be a reversal of the current US pricing policy under which mobility has been largely unrestrained.

22. A good deal of further work would also be needed to establish the relevant price elasticities which would apply to demand for private transport both in the short term and in the long term (ie after vehicle manufacturers would have had time to respond). The elasticities might vary depending on how prominently policy changes were accompanied by growing public awareness of the greenhouse effect.

B IMPACT OF CLIMATIC CHANGE ON TRANSPORT

23. At this stage only very crude pointers can be given. It is difficult to isolate the effects of climatic change on transport from the effects on the community more generally. Some effects may arise from the assumed rise in sea level from the greenhouse effect. Because any general rise in sea level would be gradual but progressive, it would increase the hydraulic loading on structures, both those associated with ports such as locks and breakwaters, and bridges, particularly the major estuarial crossings. In the South East it would exacerbate the effects coming from the existing tilting of mainland Britain which in turn have already had to be built in design of many coastal structures. Sea level rises would also have secondary effects, for example through the need to protect the London Underground.

24. Other effects on transport will depend on the new climatic patterns that develop. A general increase in temperature and greater extremes will in different ways affect critical thresholds such as the need for action on chemical de-icing on roads and runways. But greater extremes could be expected to exacerbate maintenance problems on highways generally and longer term may lead to requirements

for different types of surfacing, pavement and foundation design. The potential for major events such as flash flooding with consequent costs to transport infrastructure would increase. Maintenance costs could increase but clearly volume of traffic would be a further factor.

CONCLUSIONS

25. Transport, especially from road vehicles, is a substantial contributor to the greenhouse effect, through CO_2 emissions, an inevitable by-product of petroleum fuel.

26. Some improvements can be expected to occur anyway over the next few decades, due to improvements in vehicle design leading to greater fuel efficiency. But these are likely to be more than offset by expected increases in vehicle mileage and, to a smaller extent, by action to be taken to reduce vehicle emissions other than CO_2, for other reasons. Alternative fuels do not seem likely to make a significant contribution in the foreseeable future. The contribution from traffic restraint schemes on their own also appear limited. For these reasons action to limit transport's contribution to the GHE requires a reduction in fuel used in transport.

27. Really significant action to reduce CO_2 emissions from transport would imply significant changes in present government policy, particularly on pricing aspects and could have major public expenditure and fiscal implications if they were carried out eg through further investment in public transport or the greater use of taxation to influence transport demand.

28. Action in the UK alone would not be effective. As a minimum a collaborative strategy within Europe would be needed; and a significant impact would require joint action across most of the rest of the developed world, especially with the United States, where a particularly marked reversal of present US policies on mobility and fuel availability would be implied.

29. Turning the issue around, it is difficult to isolate the effects of climatic change on transport compared with its effects on the rest of the life of the country. A more detailed assessment would require much closer consultation with major transport undertakings, though even then would probably be fairly inconclusive.

CLIMATIC CHANGE : THE IMPLICATIONS FOR AGRICULTURE, FISHERIES, FORESTRY AND FOOD

Note by Ministry of Agriculture, Fisheries and Food

CONTRIBUTION TO GREENHOUSE GASES

1. Agriculture is a source of three of the greenhouse gases (carbon dioxide, methane and nitrous oxide) and certainly a sink for one of them (carbon dioxide). Plant growth is the principal land-based mechanism by which carbon dioxide is removed from the atmosphere, but most of the carbon dioxide which is fixed by agricultural plants is returned to the atmosphere over quite short time scales, either through the food chain or by decomposition of plant residues. Some carbon is stored in soils in organic matter, but changes in organic matter levels take place very slowly, and the net effect on carbon dioxide cycling is small. On the other hand, forest trees represent the most efficient land based means available of locking up carbon.

2. The net effect of agriculture on the carbon dioxide cycle is a small increase due to the use of fossil fuels in agricultural production with a second component added by the use of fuels in distribution and food processing.

3. Plant growth (and therefore uptake of carbon dioxide) is increased by increasing concentration of carbon dioxide in the atmosphere. This is an important factor in modelling the effects of greenhouse gasses.

4. Methane is produced from wetland and ponds, directly from ruminant livestock, and from slurry and manure. Natural wetlands are an important source on a global scale.

5. Nitrous oxide is produced by the de-nitrification of nitrates in both natural and agricultural soils.

6. Quantitative information on these inputs is scanty. There are a limited number of direct measurements, but considerable difficulties in quantifying the overall effects. Further research is required both to quantify agriculture's contribution to the greenhouse effect and to determine whether there are any changes in farming activities which could have detectable offsetting benefits.

POSSIBILITIES FOR MITIGATING ACTION

AGRICULTURE, FISHERIES AND FOOD

7. There would not appear to be any measures, apart from continued tree planting, which would appreciably reduce the increase in the level of greenhouse gases but the following possible actions might be beneficial. It must be stressed that many of the effects cannot at this stage be quantified.

8. Set-aside for arable crops or measures designed to encourage more extensive arable or livestock production could reduce inputs of artificial fertilisers which could in turn limit denitrification. On the other hand, there could for some forms of extensification be adverse consequences through the increased use of slurry. The disposal of this is less of a problem in the UK than in other Community countries notably Holland and Denmark where some restrictions have already been introduced. We know the EC Commission is considering a draft directive introducing controls EC wide.

9. In the horticultural sector, an overall rise in the atmospheric temperature would reduce the need for energy use in glasshouses. CO_2 absorption could also be promoted by increased planting of orchards.

10. The efficient use of energy in the agricultural and food industries is likely to have a significant effect on the production of CO_2. Also the sectors of the food industry which utilise fermentation will be producers of CO_2. The distilling industry (but not the brewing industry) captures large amounts of CO_2 for sale as a by-product but this has only a brief effect on the timing of its eventual release into the atmosphere.

11. There would not appear to be any significant ways in the fisheries sector of mitigating the greenhouse effect though the complex relationships between marine biological processes and climate require further study.

FORESTRY

12. In forestry, the creation of more woodland contributes automatically to increases in the uptake of CO_2. Thus, the planting of any land whether in the hills or set-aside land from lowland agricultural production stores carbon. The period of storage is long, being of the order of 50 years in British conditions, and this is extended as long as the harvested material is converted to products such as sawn wood which are either not burned or allowed to rot for a considerable time after manufacture.

ADAPTATION TO CHANGE

AGRICULTURE

13. The increase in air temperature in the range postulated by 2050 together with a rise in sea level would have significant effects in most sectors of the agricultural industry. There would also be major implications for coastal and inland flood defence arrangements. It should however be stressed that in a number of important respects (eg the impact of climatic changes on rainfall) the position is far from clear and further research is needed before the likely impacts could be predicted.

14. Assuming that the greenhouse effect was not accompanied by a major decline in rainfall, the livestock industry would benefit largely as a result of improved growth of grass and forage crops in upland and hill areas. For cereals, there would be earlier ripening and possibly higher yields. It should be possible to grow further varieties, such as maize in the South and in the North increased areas would become suitable for wheat and barley. There could be adverse effects on production in the Southern Member States and the US so the UK might become a more important producer in terms of world trade. In the case of potatoes, sugar beet, oilseeds and pulses, yields would be likely to increase and some new oilseeds and pulses could be grown.

15. The Northern limits would be increased for the production of horticulture crops; and certain sensitive crops (eg broccoli, some flowers and fruit) could be grown over a wider area in the South. The competitive production of protected crops would be enhanced due to reductions in energy inputs. On the other hand, the control of pests could be more difficult. The production of wine would also shift northwards within the Community.

16. Given that these changes will take place gradually it is considered that in the above sectors the industries could adapt with relatively little difficulty.

FISHERIES

17. The magnitude and direction of the likely changes of sea temperature are very unpredicable. If it were to be by an amount in the upper part of the range postulated, it is envisaged that northern species eg cod, haddock and herring could be replaced by southern ones such as hake, sole and horse mackerel. Although diversity could increase, abundance might decline. Improved stock management would be required to reduce the risk of collapse of sensitive stock. For fish farming, increased temperatures create potentially greater growth rates and an increase in the range of species which can be cultivated though fish diseases could become more prevalent.

FORESTRY

18. Some warming of the climate and enhanced CO_2 concentration would generally be beneficial for tree growth. Greater biomass would result, the scale of this being influenced by tree species.

INTERNATIONAL

19. On an international scale there is insufficient information on which to base a prognosis of the impact of the greenhouse effect on agriculture, forestry and the related industries and on food security. But it seems clear that changes on the scale in prospect could have significant effects on output patterns and hence on production and trade policy, both in the EC - where significant changes might be needed to the CAP - and in the wider international arena.

FLOOD DEFENCES

20. For coastal flood defences, an allowance is made at present for 30cm/100 year sea level rise. It is estimated that current expenditure would need to be increased by a factor of 2 or 3 to cope with a sea level rise at the upper end of the new potential range - 1.4 metres by 2050. Such an increase would have major implications for the cost/benefit justification of programmes and it would be necessary to consider whether to withdraw defences or, in extremis, abandon certain areas of agricultural land. The consequences for inland defences are uncertain due to the absence of forecasts of meteorological change (eg whether the possibility that catastrophic events may become more frequent).

RESEARCH AND DEVELOPMENT

21. MAFF's R&D programme includes some projects which address the implications of climatic change. In particular, ongoing research is expected to provide information on global and regional sea level trends and likely changes in oceanic climate and the implications for sea/wave levels at coasts and extreme rainfall events.

22. Further research requirements include

- large scale global ocean circulation and better coupled meteorological and deep ocean modelling

- estimates of the production of CO_2, methane and nitrous oxide by UK agriculture

- effects of climate on recruitment to and geographical emigration of fish stocks

- growth responses of current UK tree species and new species

- uptake of CO_2 by different world forest types under different management techniques

- improved understanding of denitrification by soil types

- development of techniques for altering rumen micro flora

- changing patterns of pests and diseases in agriculture and fisheries

- cultivation, utilisation and marketing of less familiar fish species and monitoring the status of marine life

CONCLUSION

23. In the agriculture, fisheries, forestry and food sectors the scope for taking mitigating action is, apart from continued tree planting, limited but some possibilities exist and could be further explored in the light of the results of further research. There are a number of possible ways in which these sectors could adapt to the changing circumstances some of which will have major economic implications. Again, additional research is needed to explore and quantify such scenarios before decisions can be made.

CONFIDENTIAL

ANNEX F

CLIMATIC CHANGE : WASTE DISPOSAL

Note by the Department of the Environment.

1. Carbonaceous material in municipal and industrial waste will be released to the atmosphere either as methane (CH_4) or carbon dioxide (CO_2) depending on the disposal route. As CH_4 is 30 times more effective as a greenhouse gas than CO_2, there is an obvious immediate advantage in arranging for as much of the emission to be in the form of CO_2 as possible.

2. Simple landfill results in the production of CH_4. This can be converted to CO_2 either by managing aerobic characteristics of the fill so that a high proportion of the carbon is emitted as CO_2, or by collecting the CH_4 and burning it. If burning the CH_4 can replace fossil fuel combustion there is an added bonus in greenhouse gas reduction.

3. Incineration of waste is another route to converting carbonaceous material to CO_2. Again, if this can be used to substitute for fossil fuels there will be an additional greenhouse gas reduction.

4. Some action on the collection of CH_4 from landfill sites is already underway in the UK, both as a response to the danger of methane build-up and as positive programmes of alternative energy supply. Modern waste incineration plant usually incorporates recovery of useful heat. To convert all the potential waste derived CH_4 to CO_2 would, however, be a major undertaking.

5. In the UK, landfill waste disposal is currently estimated to emit 3Mt of CH_4 per year. Converted to CO_2, this is about 1.3% of UK emissions due to fossil fuel combustion. There would therefore be little advantage in contemplating extreme emission reduction strategies, such as reducing the amount of waste generated, except in so far as this may reduce CO_2 emission generated in producing the material in the first place.

6. Worldwide methane emissions, primarily from agriculture, biomass burning and domestic animals are thought to be between 250 and 525Mt per year. At the lower end of the range this is similar, on a per capita basis, to the current UK per capita emission of CH_4 from landfill waste disposal.

ANNEX G

CLIMATIC CHANGE: CHLOROFLUOROCARBONS (CFCs)

Note by the Department of Environment

1. CFCs are man-made gases which are inert, relatively non-toxic, non-flammable, colourless and odourless. They are widely used as aerosol propellants, in the manufacture of soft foams (eg in furniture) and in hard foams (eg insulation, packaging), in refrigeration and air-conditioning and as solvents, particularly in the electronics industry. There are a number of different CFCs on the market. World production is about a million tonnes a year. In the UK there are 2 companies producing CFCs: ICI estimate that UK production is about 10% of world manufacture and that UK consumption is about 5% of global consumption.

2. Emissions of CFCs are depleting the ozone layer in the stratosphere, which absorbs ultra violet radiation and prevents too much of it from reaching the earth where it can affect the environment and human health. The most spectacular depletion of the ozone layer occurs over the Antarctic for a few months a year - the so-called Antarctic hole, first observed by British scientists in 1984. But there is evidence of depletion all over the world, including over the UK. CFCs are also greenhouse gases which contribute to the risk of global warming and of consequent climate change. Molecule for molecule CFCs are 10,000 times more powerful greenhouse gases than carbon dioxide (see Annex A).

3. Concern about the threat to the ozone layer led to the agreement in 1985 of the framework Vienna Convention to cover such matters as cooperation on monitoring, research and information exchange. The UK, which was closely involved in the negotiations, was one of the first countries to sign the Convention. The UK ratified it in 1987 and it came into force in September 1988. In 1980 the EC took precautionary action to limit CFC emissions by controlling production capacity and reducing CFC use in aerosols. But ozone depletion is a global problem needing global measures to tackle it. In 1987 the Montreal Protocol was agreed. The UK again took an active role in its negotiation and signed it on the day of its adoption on 16 September 1987 along

with the EC and 23 other countries. The list of signatories now stands at well over 40. The EC, UK and most other member states ratified the Protocol on 16 December 1988. It will come into force on 1 January 1989. The Protocol cuts CFC production and consumption by 50% by 1999. It also freezes from 1992 production and consumption of chemicals called halons, used as fire extinguishants, which can also damage the ozone layer. These measures are subject to review at least every 4 years beginning in 1990. The Montreal Protocol was a landmark in environmental policy making because it was the first international measure designed to prevent - on the basis of the scientific evidence available at the time - rather that cure a global environmental problem.

4. The Protocol gave world industry a signal of the urgent need to develop substitutes for CFCs and halons as well as new technologies and, in the meantime, to reduce dependency on these chemicals. ICI and RTZ/ISC have joined other producers worldwide to test the toxicity of the leading candidates to replace CFCs. Both companies are devoting significant resources to the work. ICI have announced plans for full-scale production in a few years time of an ozone-friendly chemical that will replace CFCs in refrigeration. In addition, there are practical measures being taken to reduce dependency of CFCs and halons now, by making better and more efficient use of them eg through elimination of wasteful and unnecessary uses and recovery and recycling. The British aerosol industry will phase out non- essential use of CFCs as propellants by the end of next year. This action alone will enable the UK to achieve the Protocol target of a 50% cut in CFC consumption 10 years ahead of schedule. But all sectors are taking steps on a voluntary basis to reduce use of CFCs and halons as far as possible.

5. When the Protocol was agreed actual depletion of the ozone layer was not established. Since then new evidence has come in about ozone depletion and the role of CFCs. In the light of the advice of the Government's independent scientific advisory body, the Stratospheric Ozone Reivew Group, that the Montreal Protocol is inadequate to prevent further depletion of the ozone layer the Government has called for it to be strengthened significantly so as to reduce worldwide CFC emissions by at least 85% by the turn of the century. The

UK is urging the EC as a whole to adopt the British position on the further international action needed to protect the ozone layer. It is also very important that as many countries as possible join the Protocol so that the action of some countries to reduce CFCs in not offset by growth elsewhere. Indeed if countries outside the Protocol increase their production and consumption, CFCs could rival carbon dioxide as the dominant greenhouse gas in the next century. In order to underline the importance of a worldwide commitment to reduce CFCs and to show how reductions can be achieved the Government is hosting a major international conference in March 1989, in which the Prime Minister will participate. The Government has also offered to host the meeting of the Protocol Parties in April 1990 at which decisions will be taken on strengthening the Protocol.

ANNEX H

CLIMATIC CHANGE : RESEARCH

Note by the Science and Technology Secretariat, Cabinet Office

INTRODUCTION

1. This Annex describes existing UK research on the greenhouse effect and climate change and explains how it is coordinated with international programmes. It also identifies additional research options for speeding up our understanding of climate change.

2. There are three main categories of research described, aimed at:

a. detection and improvement of predictions of climate change (both globally and regionally);

b. assessing what the impact would be of different levels of climate change;

c. developing ways of minimising the release of greenhouse gases or of adapting to some level of climate change.

The Annex concentrates on Government funded programmes with a particular focus on work to improve the detection and prediction of climate change. Earlier Annexes have also referred to work on impacts, reductions in emissions and adaptation to climate change.

ORGANISATION OF UK RESEARCH

3. Agencies - UK research into the causes and impacts of climate change is carried out at over 20 research centres. These include the Meteorological Office (Met.O), the research laboratories of the Natural Environment Research Council (NERC) and the Science and Engineering Research Council (SERC) and in the higher education institutions (HEI) with support from Met.O, NERC, SERC, Department of the Environment (DOE), Central Electricity Generating Board (CEGB) and others.

4. Spend - There is no readily available estimate of current UK spend specifically on climate research. A recent report by NERC to the Advisory Council on Science and Technology (ACOST) estimates that £98 million a year is spent on all categories of global environmental research, of which £29 million is concerned with global process studies. This latter amount, most of which comes from the public sector, can probably be taken as a broad indication of the spend on climate related research by the UK.

5. Co-ordination - Existing UK research is co-ordinated on a relatively informal basis through working contacts between researchers and cross-representation on funding committees. Where programmes are part of an international effort this also requires the UK researchers to agree a common line and some more formal co-ordinating mechanisms exist for this purpose. However, unlike the US, Canada, and Japan, there is no integrated National Climate Programme drawing together all the research work and interfacing with the development of policy. The onus, under the present arrangements, is therefore on the policy maker to bring together the available research information on which to base policy advice.

INTERNATIONAL COLLABORATION

6. Many of the UK's research programmes form part of international programmes of climate research which UK scientists have been prominent in helping to develop. The major focus is the World Climate Programme (WCP) which was

established in 1980 by the World Meteorological Organisation (WMO) and the International Council of Scientific Unions (ICSU). The WCP has four distinct sub-programmes: the World Climate Research Programme (WCRP) aimed at understanding the mechanisms of world climate and its variability; the World Climate Impact Programme (WCIP) which is run jointly with the United Nations Environment Programme (UNEP); the World Climate Applications Programme (WCAP) which has devoted its attention to the effect of climate change on human health; and the World Climate Data Programme (WCDP) which facilitates data exchange.

7. The WCRP has a number of research projects including

the Tropical Ocean and Global Atmosphere Programme (TOGA);

the World Ocean Circulation Experiment (WOCE) which brings together a programme of ocean observations using satellites, ships and other platforms;

the International Satellite-Cloud Climatology Project (ISCCP) to study the role of clouds in the climate system;

the International Satellite-Land Surface Climatology Project (ISLSCP) to study the interactions between land and the atmosphere;

and the Global Energy and Water Cycle Experiment (GEWEX) aimed at studying the interactions of energy systems and the hydrological cycle.

8. A major new initiative established by ICSU in 1987 is the International Geosphere-Biosphere Programme (IGBP) or Global Change Programme. Its emphasis is likely to be on terrestrial biosphere-atmospheric chemistry interactions; marine biosphere-atmosphere interactions; biospheric aspects of the hydrological cycle; and effects of climate change on terrestrial ecosystems. This will complement WCRP which concentrates on the physical and dynamical aspects of the global climate system. There will need to be close and

effective collaboration between the two programmes, especially in studying the carbon and other biogeochemical cycles and their role in controlling climate change.

9. These international science programmes are usually initiated by groups of interested scientists rather than as a consequence of pressure from potential users of the knowledge likely to be created. Participation is voluntary; there are no assessed national contributions.

10. In addition to the wider international programmes, two current European Community (EC) programmes, on Environmental Protection and Climatology and Natural Hazards, contain elements relevant to climate change. The EC has proposed greater funding of environmental research on 'global change in the world environment' in the R&D Framework Programme which is due to be reviewed next year. The DOE will be leading further discussions with the EC on the development of this Programme and its coordination with other international programmes.

11. The other main area of international collaboration is on Earth observation from space. Satellite observations will be needed to provide global coverage of certain aspects of the environment for climate modelling; they also provide a means of collecting relevant data from automatic and remote data recorders deployed on the land surface or in the oceans. The UK has played a significant role in this area through the European Space Agency (ESA) and in developing instrumentation for European and US satellites. The British National Space Centre (BNSC) co-ordinates the interests of the Department of Trade and Industry (DTI), SERC, NERC and the Ministry of Defence in this area.

12. The main contribution to improving the basic global satellite meteorological observing system has been through support of the European geostationary satellite, METEOSAT. The UK contributes 16% to the cost of these satellites through the Met.O budget.

13. The UK has a major involvement in the ESA Earth Resources Satellite (ERS-1) programme, mainly through the DTI budget, but with some SERC funding. This

satellite is due to be launched in 1990 and will provide global all-weather measurements mainly relevant to ocean-atmosphere processes. Data from ERS-1 will be made available through the new UK Earth Observation Data Centre which is being established in conjunction with the private sector through the DTI budget. Additional resources are necessary, however, to further process the data to produce parameters for climate modelling.

14. The UK has also agreed to contribute through the DTI budget to the Columbus Polar Platform and is taking the lead in ESA's participation in this US-led space station project. The polar platform is due for launch in the late 1990's and will provide for a follow-on to the ERS-1 programme, although with a gap in the mid-1990's. ESA is currently reviewing its earth observation programme to focus on four main strands: environment-monitoring, earth resources management, operational meteorology, and solid earth. On present priorities and funding the UK will support only the earth resources and operational meteorology programmes in any significant way, and then only from the polar platform era. Resources have not been allocated so far to support ESA activities in advance of this in the environment-monitoring area including an ERS-2 mission to give data continuity to the ERS-1 sensors.

15. In the past the UK has played a significant role in developing instrumentation for European and US satellites. An example is the UK participation in NASA's Upper Atmosphere Research Satellite (UARS) which is due to be launched in 1991 and which will provide a comprehensive set of measurements of atmospheric constituents, including ozone. The UK, through SERC, is providing one of the principal instruments and part of a second experiment to fly on UARS. Such joint ventures have given UK scientists access to the data from all the instruments on board the relevant satellite, in exchange for providing one key instrument. This arrangement has been highly beneficial and it is desirable that this kind of collaboration should continue in the future, for example, in the development of instrumentation for the polar platforms planned for 1997 and beyond into the next century. Funding for UK groups to take part in instrumentation for the polar platforms has not yet been fully established.

THE MAIN EXISTING RESEARCH PROGRAMMES

Improving Predictions of Climate Change

16. Analysis of global temperature records over the last century appear to indicate a gradual temperature increase which some scientists suggest is the start of global warming due to increasing concentrations of greenhouse gases in the atmosphere. However, as yet there is no statistical certainty and it is unlikely that such records will provide a clear signal for a further 10-20 years. If the effect is indeed real, delaying action this long will be too late to prevent significant global warming by the middle of the next century.

17. The major research emphasis is therefore to improve predictive modelling of climate change. This requires the development of global 3-dimensional climate models. The provision of adequate observational and experimental data is also needed to help improve understanding of physical, chemical and biological processes that are at present inadequately represented in the models, and thereby to provide more realistic inputs, to check and verify model predictions and to monitor continuously the global climate in order to detect changes that might result from greenhouse warming. There is a particularly high priority to improve the representation of basic atmospheric and ocean processes and the interactions between the atmosphere and the Earth's surface; this will need to draw on a wide range of disciplines from the core sciences.

18. Outside of the USA, only the UK (Met.O) has published results from advanced climate models. Other groups have the potential to enter this area, including teams from Australia, Canada, the Federal Republic of Germany and France; it is expected that Japan and the USSR may not be far behind. Priority within the Met.O programme will be given to increasingly realistic carbon dioxide simulations. Important topics for developing a better framework

for prediction are cloud-radiation feedback and ocean feedback using coupled atmosphere-dynamical ocean models. The Met.O has perhaps the most advanced model of the global atmosphere coupled to simple models of the ocean and of land and sea ice. Initial work on atmosphere-ocean modelling has been undertaken through a joint Met.O/NERC programme at the Hooke Institute in the University of Oxford. Discussions are underway to develop an enhanced joint programme.

19. Two other major climate-related modelling projects are also underway. A group working at the NERC Institute of Oceanographic Sciences Deacon Laboratory (IOSDL) is developing a high resolution model of the Antarctic Ocean circulation and its effects on climate. The NERC is also sponsoring direct university involvement in atmospheric modelling through the Universities Global Atmospheric Modelling Group (UGAMP), involving scientists from five university departments and the SERC Rutherford Appleton Laboratory (RAL). The UGAMP core-team is situated at the University of Reading which has close ties with the Met.O and the European Centre for Medium-Range Weather Forecasting. A longer term university programme is under consideration.

20. The development of a reliable, fully coupled ocean-atmosphere model requires realistic data on the atmospheric and oceanic processes which govern the vertical mixing of heat and momentum in the ocean; air-sea interaction is a high priority research area in the WCRP.

21. Satellite instruments on ERS-1 and on board other satellites provide substantial data to model the interaction between the surface layers of the ocean and the atmosphere. However they are unable to penetrate much beyond the surface. Observations of weather systems in the deep ocean, of temperature and salinity structure, of currents and of heat and water flows between ocean basins, will require a sustained programme of measurements on the ground - from dedicated research ships, submersibles, buoys etc. The international research programme WOCE is addressing this task. NERC hosts and helps fund the WOCE International Planning Office. It has also, with support from the Met.O, encouraged the European Science Foundation to support the development of a co-ordinated European input. Only a few nations have suitable research ships

and other resources to contribute to the WOCE effort and the UK is one of these. NERC has allocated £9 million over 5 years involving Research Council and higher education institutes, and is considering the possibility of a further £6 million.

22. Biogeochemical processes will also influence the dynamics of the cycling of the elements in the ocean and related atmospheric exchanges, especially of carbon. One major uncertainty is the role of plankton. In addition to WOCE, another international programme, the Joint Global Ocean Flux Study has a major focus on this problem. The UK contribution to the latter will be through the NERC Biogeochemical Flux Study, a community programme involving both NERC and higher education institutions.

23. The role of the cryosphere in the climate system needs to be better understood. The main task is to develop dynamically and physically based interactive sea-ice models to incorporate in coupled ocean-atmosphere models, and to develop parameterisations of the physical processes associated with snow and ice covered land surfaces. The main UK work will be provided by the NERC British Antarctic Survey (BAS) in co-operation with the Met.O and the University of Cambridge Scott Polar Research Institute.

24. The transfer of water, heat and momentum between the land surface and the atmosphere is a critical process for climate and for plant growth and structure. One of the most pressing research priorities for climate-model simulations is to improve understanding of the so-called sub-grid scale physical processes, so that their integrated statistical effects can be better incorporated into such models; these processes are particularly important in relation to the prediction of the effects of climatic change. Relevant research on land-surface water balance is already underway at the NERC Institute of Hydrology and higher education institutions and also at the Met.O. At present the international focus is the ISLSCP of the WCRP and NERC is one of the principal investigators in the First ISLSCP Field Experiment. The proposed IGBP is also likely to have a major focus in this area.

25. The IGBP will also focus on biogeochemical processes on land. The roles of natural plant, animal and microbial communities in the cycling of greenhouse gases is another major areas of uncertainty. The effects of man's activities both in disturbing these natural communities and in introducing forms of land management which affect production of these gases need to be studied. The Research Councils and HEI's will be able provide an important input to such studies.

26. A further area demanding basic research concerns cloud processes. These play a crucial role on the climate system particularly in regard to cloud-radiation feedback and effects on the hydrological cycle and energetics of the atmosphere. The Met.O operates a well instrumented long-endurance aircraft for making measurements of the dynamical and microphysical properties of clouds and their radiative effects; this enables the UK to participate effectively in international climate programmes investigating cloud processes.

27. A good deal of useful though generally widely distributed effort goes into the analysis of climatological records to establish past climatic changes on all time scales, from seasonal fluctuations to ice ages. Although of little predictive value in itself, this provides a baseline against which the significance of recent fluctuations and of predicted effects can be assessed.

28. In addition to work at the Met.O on its substantial climate archive, much of the work on conventional instrumental records is funded by a variety of short-term contracts to University departments, notably the University of East Anglia and the University of Birmingham. The research group at NERC (BAS) has reconstructed past climates going back thousands of years from the analysis of ice cores. The carbon dioxide content of past atmospheres has been deduced from analysis of air bubbles trapped in the cores and correlated with the prevailing temperatures deduced from oxygen isotope ratios. Analysis of ocean sediment cores can also contribute to understanding of past climates, climate variability and sensitivity, over periods of hundreds of thousands to millions of years. A number of cruises of the international Ocean Drilling Program (ODP), of which the UK is currently a member, have been or will be directed towards a better understanding of past global climate.

Climate Impact Assessment

29. At present the estimated range of potential climate change remains wide. There is also little agreement in the scientific community on the scale of climate change that could be tolerated. Regional scale forecasts required for accurate assessment of national impacts are unlikely to be available from predictive modelling for another 15-20 years. Nevertheless a number of countries are carrying out national assessments of the implications of future climate change using various possible scenarios as a base. Such assessments involve detailed scientific and socio-economic analyses.

30. Detailed impacts work funded by UK government is so far modest. Earlier this year the DOE commissioned NERC to produce a series of desk studies on "Possible Impacts of Climate Change on the Natural Environment in the United Kingdom". Both institute and academic scientists were involved in these studies, the results of which have now been published. A specimen climate scenario, plausibly consistent with a doubling of carbon dioxide levels above pre-industrial levels, was provided as the basis for studies covering effects on trees and forests (natural and commercial), on UK crops, on ecosystems and processes of conservation and amenity interest, on freshwater ecosystems and on coastal ecosystems of conservation and amenity interest. The report identified a number of research requirements for improving impact assessments in these areas.

31. This study complements the work of others, including industry, on other impacts. For example, other government departments have a role in determining possible impacts in relation to the industries for which they have responsibilities: various aspects are discussed in previous Annexes. The Ministry of Agriculture, Fisheries and Food (MAFF), in addition to its concern on impacts on agricultural production and fisheries, also has a particular remit in relation to sea levels and flood protection. The Department of Health will be concerned with effects on health as well as any implications for the health care delivery system.

32. A number of universities have also carried out work in this area. The main centres are the Atmospheric Impacts Research Group (AIR) at the University of Birmingham and the Climatic Research Unit and School of Environmental Sciences at the University of East Anglia (UEA). With funding from NERC and the Economic and Social Research Council (ESRC), the AIR Group hosted a Workshop on the "Implications of Climatic Variability for Industry in the UK" in December 1987. The UEA has produced recently a study of the impacts of climate warming on the UK and NW Europe, funded by Friends of the Earth.

Responses to Climate Change

33. There are no major government funded programmes whose primary purpose has been aimed specifically at reducing the emission of greenhouse gases or adapting to higher levels. The Department of Energy is, however, concerned with the implications of the greenhouse effect for energy production, and its work on non-fossil fuel energy sources and improved energy efficiency (described in Annex C) is clearly relevant. The Agriculture Annex discusses research themes on adaptation to climate change. Industry has already funded substantial research into alternatives to CFC's, and further work in the transport sector on vehicle and engine design and use of alternative fuels will be relevant (see Annex D). Whilst there is substantial expertise in Government research laboratories and the science base that could help with some aspects of research on responses to climate change in the future, the main financial responsibility is likely to fall on industry.

34. In devising potential response strategies to the greenhouse effect it will be important to take account of any potential environmental disbenefits of the response strategies themselves. Thus close links will need to be maintained with the DOE and also MAFF. Again the science base, in this case NERC, the Agricultural and Food Research Council, the ESRC and the HEI's will be able to contribute their research expertise in analysing these problems.

FUTURE RESEARCH REQUIREMENTS

35. The main priorities to improve the predictive capability are enhancing development of climate models and improving the representation of atmospheric physical processes and ocean processes in these models. On present progress it is estimated that it will take the next 5-10 years to resolve the major uncertainties and thus narrow down estimates of the scale of any future changes in climate. Provision of additional resources could accelerate some of the model development work. A modest strengthening in the UK input to planned observational programmes to investigate the processes that need to be represented in the climate models would build on existing UK strengths and enhance the UK's international profile.

36. The requirement for observational data entails not only the continuation of existing programmes and the initiation of new programmes of ground and airborne observations to investigate processes, but also the maintenance of long time series of data including meteorological data, sea level rise, marine plankton, ecological observations on land, and polar programmes, especially measurements of changes in sea ice and land-based ice caps, against which future changes may be assessed.

37. In addition to ground-based measurements, reference has already been made to the importance of global observations from satellites. There is a need to develop this work, in particular to ensure adequate provision for data handling and interpretation, and to support UK investigators in designing appropriate instrumentation for future Earth observation satellites.

38. A continuous series of data observations from satellites flying over a number of years is required to establish the database needed for reliable climate models. To ensure continuity between ERS-1 and the polar platforms, it has been argued that a near copy of ERS-1 should be built for launch in 1994. An important change from the ERS-1 payload is the proposed inclusion of

an atmospheric chemistry instrument. There is strong support in Europe for this, with only France and the UK witholding support. The estimated cost of UK participation is £50 million.

40. <u>Co-ordination</u> - The UK scientific community on climate-related research is concentrated chiefly at a few centres - The Met.O, the research laboratories of NERC and SERC and within the HEI's, primarily at the Universities of Oxford, Reading, Cambridge, Birmingham, and East Anglia. There is ample opportunity for purely scientific discussion at both national and international level with, if anything, too many international meetings. However there is no one national focus for climate research for deciding how the UK can best contribute to the study of the global problem, for assessing on a regular basis the coherence and efficiency of the national research effort and for ensuring a unified approach to international research programmes. Consideration might be given to developing existing mechanisms, such as the Met.O/Research Councils' Climate Committee to co-ordinate research on scientific assessment and impacts. Consideration also needs to be given to improving co-operation at the interface between research findings and policy development. The Stratospheric Ozone Review Group sponsored by DOE and the Met.O sets a good example of what can be achieved and a similar group might be considered to deal with Climatic Effects of Greenhouse Gases.

ANNEX I

CLIMATIC CHANGE: THE ECONOMICS OF POLICY RESPONSES

Note by HM Treasury

Summary

The adverse effects of climatic change are potentially catastrophic, but distant and uncertain. Governments cannot therefore stand back, but must make an assessment of the problem and of what needs to be done. But it is of the greatest importance to bear in mind that unilateral action by any one country is unlikely to have a significant effect on climatic change. The scale of the problem demands international action; but moreover a country taking unilateral action damages its own competitiveness and allows others a "free ride". Co-ordinated international action both is more effective in meeting the problem of climatic change and minimises the scope for "free riders".

2. The measures available for concerted international action fall basically into two types: measures working on prices, through levies, taxes or the sale of licences, to achieve change through the market; and regulation. The former is intrinsically more satisfactory, but will not always be practicable.

The problems

3. From an economic point of view, the problems of preventing possible climatic change induced by gaseous emissions are similar to the problems of pollution more generally. Pollution is often restrained by government or voluntary measures, through the price mechanism or regulation, because there is no other way to face those who produce it with the costs which their pollution imposes.

4. This is partly because, without such intervention, the cost of the pollution does not fall directly on its producers. (In technical terms the cost is an "externality".)

5. It is also because, even though people might willingly pay for, say, clean air, the benefits would be enjoyed by those who did not pay just as much as by those who did pay. Many would therefore try to be "free riders" and avoid paying, knowing that they would enjoy the benefits of other people's payments.

6. For these reasons it is usual for developed nations to have extensive public measures to control pollution. Increasingly these extend to international agreements.

7. Although world atmospheric pollution presents no new economic principles the problems of control are, from an economic perspective, especially severe because:

(i) The costs are spread extremely widely and unevenly, so that (especially because of the free rider problem) it may be difficult to get international cooperation.

(ii) The costs are not easily perceived and are very distant (in contrast to, for example, fresh water pollution, or smoke, or the killing of trees), yet they are potentially catastrophic, and very hard or impossible to reverse once they become physically obvious. There is therefore an exceptionally important role for governments in developing a strategy of positive responses, including whatever is the appropriate level of public awareness.

The solutions

8. There are broadly two ways in which the production of polluting effluents is controlled.

9. The first, and more satisfactory, is through the price mechanism. Governments can tax, or raise levies from, polluters, or sell polluters rights to produce certain levels of effluent. This, in principle, can bring the costs of pollution to bear

directly on producers, who will then adjust their outputs and methods of production (including research into new methods) just as they do to materials or labour costs. It is a "market" solution.

10. In practice, charges for polluters are often very difficult to set up and administer. Far more often, effluent emissions are controlled by physical constraints, either prohibiting them, or imposing maximum levels of emission.

11. Physical controls are less satisfactory than taxes or auctioned licences in that the cost of pollution is made to fall only very crudely and partially on producers. It leads some producers to pay more on pollution control, and some less, than would be justified by the cost of the pollution they create; and to less efficient research into less polluting methods of production. It is also less satisfactory in not being a source of revenue which could be used to finance prevention measures. However it is much easier to introduce and maintain controls of this kind.

Discussion

12. Free market forces are unlikely to deal with the problem of pollution and climatic change, even if world populations were to be fully informed about the potential dangers. This is because, even setting aside scientific uncertainties and problems of administration, there is generally no effective way in which the prospective future sufferers can restrain the polluters other than through governments. Things are made worse by the free rider problem: any country which does not act against this pollution will still benefit from the action of others and may derive a competitive advantage from not acting against the pollution itself. It may therefore have an economic interest in trying to avoid taking action On the other hand there may also be benefit in taking action, even if others do not do so.

13. Where there is a scientific case for action to control world atmospheric pollution some progress can be achieved, as now, by public opinion leading to legislation in some major producing

countries. However this is more likely to be effective for products such as CFCs and motor pollutants which are seen as "man-made" and perhaps as easily avoidable, than for a superficially benign and commonplace effluent such as carbon dioxide. Independent action by countries will in any case often be strongly constrained by arguments of fairness, especially in trade, in comparison with other polluting nations.

14. For the UK, there is fortunately an opportunity for tackling this awkwardness through the EC. Discussion on the Internal Energy Market is now beginning and initiatives aimed at taxing polluters would be likely to be received positively by other member states. Furthermore, UK industry would not then be in a strong position to complain about a relative loss of competitiveness, since their main competitors are in the Community and would be similarly affected.

15. The "market" approach to cooperative action between countries would be international agreement on the cost which, say, each tonne of particular effluent would impose on the world, and a tax set at this level on all who produced it. In practice, a more realistic objective might be international agreement on quotas for future national emissions, either in total or from particular activities - although introducing and monitoring even this simpler objective could require formidable amounts of information. Within nations, there would be scope for applying such quotas at least partly within a market framework, by some auctioning of rights to those producers who wished to use polluting processes.

16. Any such international agreement would need strong monitoring, and probably widespread international public support, given the direct incentives on each nation or industry to free ride on the efforts of others. On the other hand it is arguable that a firm lead by one or a few countries could help to shift opinion in others: but a strong case for that consequence would need to be made out.

HM Treasury
20 December 1988