

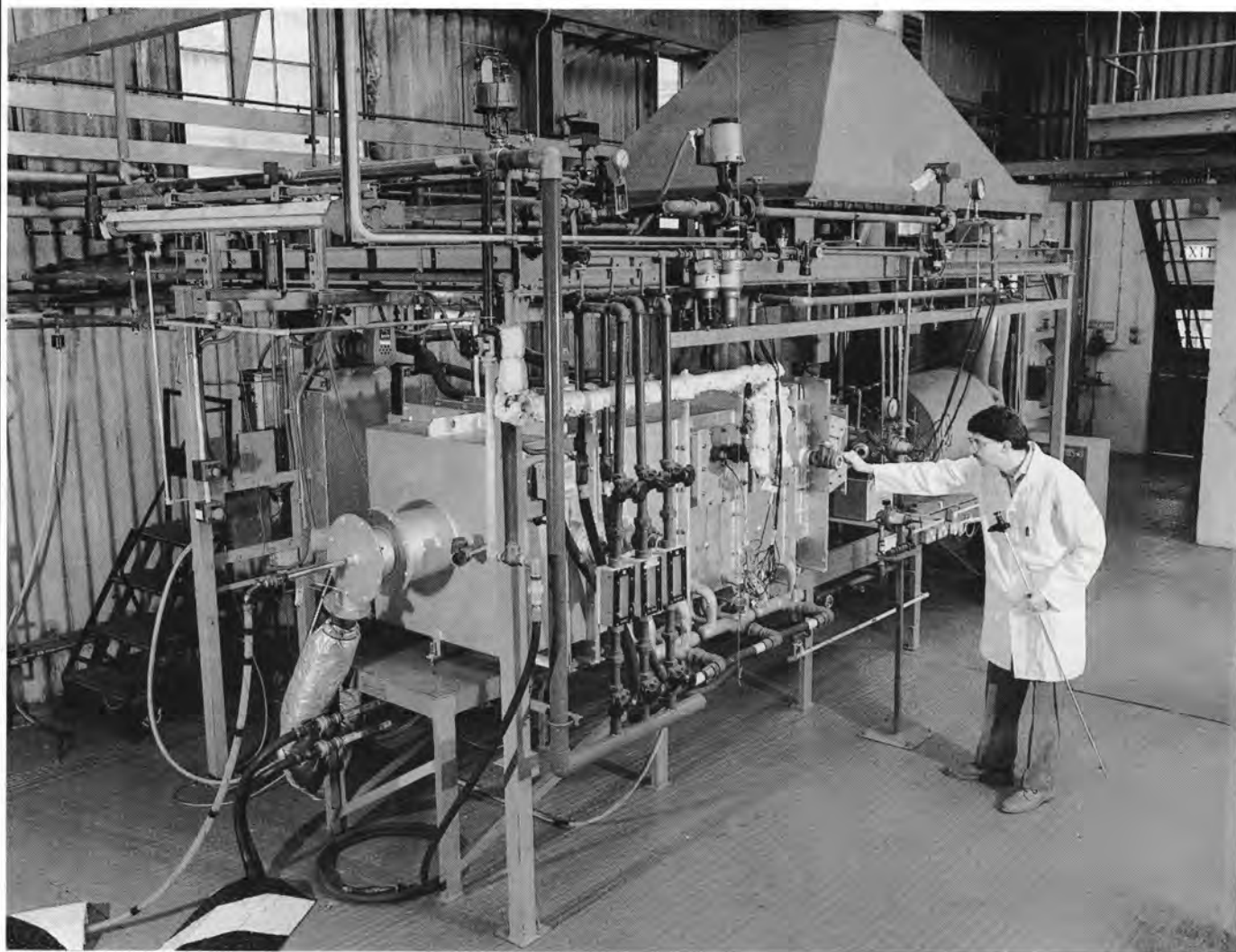
# ENERGY WORLD

The magazine of The Institute of Energy

Number 185  
February 1991



**INSIDE THIS ISSUE:**  
Features on global warming  
PLUS 1990 Robens Coal  
Science Lecture



CRE Technical Services is a consultancy operated by the British Coal Corporation. Drawing on the expertise of the Coal Research Establishment near Cheltenham, the organisation offers advice, test and development facilities on many aspects of coal processing, combustion, and handling.

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# ENERGY WORLD

FEBRUARY 1991

Number 185

Published by The Institute of Energy  
18 Devonshire Street, London W1N 2AU  
Telephones: *Editorial:* 071-580 0008. *Administration:* 071-580 7124.  
*Membership, Education and Journal subscriptions:* 071-580 0077.  
*Fax:* 071-580 4420.

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Printed by Headley Brothers Ltd, The Invicta Press, Ashford, Kent

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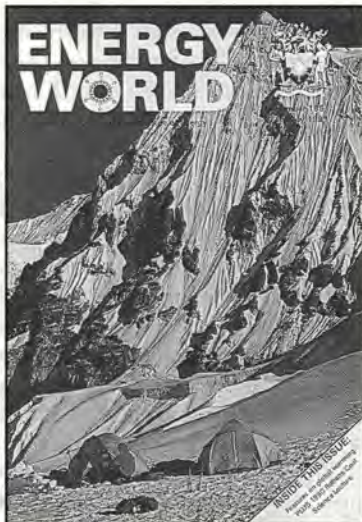
## COVER STORY

This month's cover photograph was taken on the recent GEC Young Employees Himalayan Glaciochemical Expedition to Nepal in 1990, and shows Mount Cho Oyu in the background.

The objective of this expedition was to recover a glaciochemical record from a 30m ice core above 6000m in the Khumbu Himal region of Nepal. This should provide a record extending from 15 to 30 years. The resultant data base will provide the framework for describing and understanding aspects of atmospheric chemistry, circulation and short-term climate change, and could help our understanding of the possible effects of global warming.

The team of GEC apprentices, technicians, students, secretaries and engineers undertook a 25-day return trek from Kathmandu to the accumulation zone of Cho Oyu's west glacier, Khumbu Himal, where they recovered the ice core and samples from snowpits surrounding the ice core site.

The photograph was kindly lent to us by Barry Roberts, Expedition Advisor and Development Training Co-ordinator, GEC Management College, Dunchurch.



## CONTENTS

Viewpoint	2
<b>NEWS</b>	
International News	3
Home News	4
Institute News	5
Commercial News	22
<b>FEATURES</b>	
<b>An overview of CO<sub>2</sub> emissions</b>	7
Author: Dr G G Thurlow Honorary Secretary of the Energy Industries Club	
<b>Conference Report — The Costs of Flue Gas Desulphurisation</b>	12
Author: Dr Anupam Sanyal	
<b>Options for limiting CO<sub>2</sub> from power generation</b>	14
Author: Ken Gregory Leader, Atmosphere Environment Section Operational Research Group British Coal Corporation	
<b>REGULARS</b>	
Book Reviews	19
Readers' Letters	20
Engineering Council	21
<b>DIARY</b>	
Events	23
Conferences	24

### TERMS OF CONTROL

Energy World is circulated free of charge to all paid up members of The Institute of Energy. To libraries, organisations and persons not in membership it is available on a single subscription of £45 for 10 issues. Energy World is also available with the Journal of The Institute of Energy (quarterly) at a combined annual subscription of £140.



# Will the lights go out?

IN THE days before Parkinson (BP as we call it), electricity customers enjoyed 'security of supply' and the electricity industry laboured under an 'obligation to supply'. The idea simply was that if you paid your bills you had every reason to expect a reliable supply of electricity. The Conservative government assures us that privatisation has not compromised this guarantee to electricity customers. But, of course, it has.

The 'obligation to supply' was commonly seen as applying to the generating side of the industry — the CEGB in England and Wales — rather than the Area Boards. While the Tories have notionally transferred the obligation from the generators to the Regional Electricity Companies, it is still restricted to meeting the 'generation security standard'. In other words, 'security of supply' is understood by the government to refer to failures due to 'insufficiency of electricity generation available' and is not meant to cover failures in the distribution system.

In the run-up to privatisation, there has been a loosening of the definition of the 'generation security standard'. In December 1987, the CEGB admitted to the Energy Select Committee: "the industry recently reduced its generation security standard from one based upon the acceptability of interruptions to supply in three winters in 100 to one based on the acceptability of interruptions in nine winters in 100." I haven't asked but I would no doubt be assured that this had absolutely nothing to do with privatisation.

There is another insidious threat to security of supply. Successive distribution company annual reports record with pride substantial staff reductions, portraying them as increased efficiency. However, these reductions also mean that when there is a blizzard or other emergency there are fewer people available to cope. There have also been some significant increases in pre-arranged cuts in supply: up in three years by 22% in the North, 27% in the East Midlands, 57% in the Midlands and 74% in South Wales. Perhaps this is what the government calls getting in shape for privatisation.

There are some interesting differences between the January 1989 draft and the February 1990 final version of Condition 10 of the Public Electricity Supply Licence issued to the distribution companies. It is all very well telling the RECs that they must meet the 'generation security standard', but that does leave the question of how to ensure that they do what they are told. In the earlier draft, the RECs were obliged to describe to the Director (OFFER) every year "the arrangements made or to be made by the licensee to meet the generation security standard in each of the seven succeeding financial years" referring to "data, assumptions and demand forecasts." By last February this obligation had become far less specific: "The licensee shall upon request by the Director provide to the Director such information as the Director may require for the purpose of monitoring compliance with this Condition . . ."

This gets us to the core of the fears about security of supply. Under the old 'BP' set-up, the CEGB was required to plan for future years to ensure that security of supply would still be maintained. But of course planning was public enemy number one to the right-wing Tories who dreamt up the present

shambles. The idea that the RECs would be able to produce substantive seven-year plans with market forces let loose was never credible.

For one thing, the RECs are no longer in a position to know who their customers are going to be. Some have already lost major industrial customers to the generators or to other RECs, and the Prospectus shows that several are concerned about the possible impact of CHP 'own-generation'. They may be able to compensate for losses by poaching business from another REC but when planning for the future the only thing they know is that they don't know.

Even if the RECs knew what the demand was going to be they still couldn't plan the supply. Developing generating capacity is simply not their job, given the unnatural break between generation and distribution. They can set up some plant of their own or strike contracts with independent generators (who will not have the proven competence of the CEGB's successors). But for the rest they will depend upon National Power, PowerGen, Nuclear Electric and the pool. In short, the RECs cannot predict electricity demand and they cannot plan electricity supply.

In the end, 'security of supply' depends on sufficient generating capacity being developed, with a reasonable geographical spread and a range of energy sources. Planning by the RECs cannot assure this and neither can planning by National Power and PowerGen because they are competing with each other and with the independent generators. As National Power has stressed: "The successors to the CEGB no longer have the obligation to supply and no longer, therefore, the obligation to consider or plan for the long-term diversity or security of primary energy sources for electricity generation."

The Conservatives say not to worry because the market will provide. Looked at nationwide we do at the moment have sufficient capacity — thanks, of course, to planning, not market forces. We also know that the generators are talking of a big increase in gas-fired generation because it is cheap at the moment. But there is no evidence that the market is paying due regard to geography and diversity. That's not the sort of thing markets do. Even the government has acknowledged this by insisting that nuclear power stations be run on baseload while cheaper conventional stations stand idle.

Neither the RECs nor the generators can plan to deliver security of supply under the new regime. No one would wish to start from here, but Labour will have to. We intend therefore to vest new powers in the National Grid Company so that it can "plan for the long-term diversity or security of primary energy sources for electricity generation." It will be able to prevent the building of power stations which are in the wrong places or of the wrong type and to secure the building of power stations which are genuinely needed.

Labour's top priority will be to promote energy saving rather than energy sales. That will help security of supply as well as saving money, saving energy and saving the environment.

**Frank Dobson MP**  
*Shadow Energy Secretary*



## Britain should follow Europe

BRITAIN could develop a new era of low-cost emissions-free energy supply if it followed the European example and established a series of local heat and power production and distribution units.

Dr Eugène Keppler, Secretary General of the International Union of Heat Distributors (UNICHAL) told a meeting of the Major Energy Users' Council that self-contained units would operate primarily in the consumers' interest.

"It would be an advantage to have in a community one responsible person to ensure that individual requirements for electricity, gas, distributed hot water and heat are given their appropriate priorities," said Dr Keppler.

When questions about economic justification were raised, the meeting was told that several modern plants in Europe operate so cost-effectively that they are shut down in the summer months and have electricity surplus in mid-winter.

UNICHAL members operate an installed capacity of 140 000 MW for heat, power and other services in combination through a network of heat distribution covering 44 000 kilometres.

The meeting was hosted by Peter Rost MP, a member of the House of Commons Energy Select Committee.

## Suez oil discovery

BRITISH GAS has made an important oil discovery in the Gulf of Suez. The find is regarded as the most significant in the area for nearly a decade.

In partnership with Yukong Ltd and Union Pacific Petroleum Suez Ltd, British Gas made the discovery with their first wildcat well in the North Zaafarana concession. The cumulative flow rate from five intervals between 5060-6428 ft was more than 7500 barrels of oil per day. Designated 'HB 78-2 Warda', the well flowed oil with an API gravity ranging from 18 to 24 degrees. The well was drilled to a total depth of 8400 ft and has been temporarily suspended. The rig used was the Santa Fe 124 and the location is 6 km offshore.

Appraisal drilling was scheduled to begin early in 1991. An exploratory 3D seismic survey was acquired before drilling the well and this will reduce uncertainty in future drilling.

The consortium for which British Gas acts as operator has two concessions covering more than 241 000 acres in the northern Gulf of Suez.

## Japanese nuclear fuel contract

AEA THERMAL Reactor Services has been awarded a contract by Kansai Electric Power Company of Japan for the examination of irradiated fuel from the Ohi 1 pressurised water reactor.

The work, which is scheduled for early this year, will be undertaken by the Fuel Performance Division of AEA Thermal Reactor Services at Windscale.

Examination of irradiated nuclear power station fuel has been carried out for many years to provide invaluable information about the operating characteristics and performance of both fuel and reactors.

AEA was awarded the contract because of its long experience in post-irradiation examination on a wide range of fuel from numerous electricity utilities and research centres, both in the UK and overseas. The work will comprise a series of examinations on rods from an Ohi 1 fuel assembly, from which an assessment will be made on their performance. The fuel assembly will be the first to pass through AEA's new underwater examination and dismantling facility.

## Inca technology for Peruvian energy

THE MANUFACTURE of small bronze Pelton turbines (1 kW to 15 kW) using the ancient lost-wax casting method created interest at a two-week training course run in Cuzco, Peru. The turbines are used in small-scale hydro projects generating power in remote, hilly areas away from grid supply.

Organised jointly by the Intermediate Technology Development Group and the German

government agency, GTZ, the course involved participants from Peru, Nicaragua, and Colombia, who learned the basic techniques of lost-wax casting — originally used by the Incas for making jewellery — and specification of small turbines.

Casting small Pelton wheels in one piece using the lost-wax method leads to a stronger product, as there is no need to weld the buckets to the hub — the method used for sandcasting larger turbines.

With the recent removal of subsidies on diesel, the economics of small-scale hydro are more attractive for communities who can afford the \$1200 to \$1500 investment in the complete system. And lost-wax turbines can be made for about \$400 each, which compares favourably with the current price of crossflow turbines of similar capacity.

## New Swedish oil reserves

ANALYSIS OF crude oil samples pumped from the Sil-

jansringen crater borehole in central Sweden indicate the discovery of a major new oil reserve 6km below the crater surface.

High concentrations of nickel and vanadium discovered in samples taken from the Gravberg 1 borehole, by Swedish exploration company Dala Djuggas Produktions AB, provide the strongest evidence of the deposits.

Surface tests by three laboratories reveal high concentrations of sodium and calcium in the salt water, the pungent smell, colour and ignitability associated with crude oil deposits.

Preliminary results of bacteria cultures from the 15 cubic metres sampled last autumn also suggest deposits of natural oil. A second borehole, Stenberg, will be sunk at the site in March.

Exploration of the Siljansringen crater, formed by the impact of a gigantic meteorite 360 million years ago, was based on the deep gas theory of the Russian scientist Mendelejev that methane from the inner Earth has, during millions of years, escaped through fractured rocks to form oil reservoirs.

# ACID RAIN

## - A Perspective

EDITORS  
John Ward  
David Browning

Published by The Open University and The Institute of Energy, price £10, from the Publications Department, 18 Devonshire Street, London W1N 2AU.



## CORGI acquires teeth

THE COUNCIL for the Registration of Gas Installers (WRGI) has been formed for the Confederation for the Registration of Gas Installers. This is not just a cosmetic change of name as the old CORGI, now 21 years old, has been given a set of teeth.

Registration used to be voluntary. Now, under the Gas Safety (Installation and Use) (Amendment) Regulations 1990, any employer or self-employed person who works on gas fittings must be a 'member' of a class of persons approved by the Health and Safety Executive. CORGI will act as the registration body for the new mandatory registration scheme. The scheme is intended to ensure that all gas work under the Gas Safety Regulations will, in future, be done in a safe and competent manner. CORGI will monitor the competence and safety standards of registered installers, and will provide information and advice on good safety practice.

All gas installation businesses, including self-employed installers, must apply to register with CORGI by 30 March 1991. Any unregistered business which does work with gas fittings after this date could be subject to prosecution. George Banks, the Director General of CORGI said at the launch. "It is a source of great satisfaction that we are now launching a new, independent registration body with statutory backing. It will bring great benefits to all reputable gas installers and to all gas consumers.

"CORGI is ready to register all gas installers. We are contacting all our existing registrants about arrangements. Gas installers who are not registered should write to CORGI, PO Box 15, Basingstoke, Hants RG2 0WZ or tel. 02526 819810 for a registration pack."

## New British Coal chairman

NEIL CLARKE, current Chairman of Molins and Genchem Holdings, has been appointed to succeed Lord Haslam as Chairman of British Coal when his appointment expired at the end of 1990. A city industrialist, Mr Clarke initially takes up his five-year appointment on a part-time basis.

## Experiments reveal fission product chemistry

THE BEHAVIOUR of fission product releases following a severe reactor accident is being assessed in a £1 million experimental programme carried out for the Commission of the European Communities and the Health and Safety Executive by AEA aerosol science and chemistry experts. The results have mixed implications for reactor safety case studies, particularly future LWRs.

The programme also provides important data which will be used to validate computer codes dealing with the consequences of severe reactor accidents. However, the codes currently do not take account of some of the

important chemical processes likely to occur after a severe reactor accident, as vapours released by melting fuel interact with aerosols formed from melting fuel cladding, reactor structural materials, and boric acid used as a soluble neutron absorber.

A major database for code testing and development is now available from the exhaustive data reports produced on 20 experiments conducted in the rig during 1989-90, and this year the rig will be used to undertake a programme of work for the HSE to assess iodine chemistry in the containment.

## New 1000 MW/CCGT power station at Barking Reach

THAMES POWER Ltd and the London Borough of Barking and Dagenham (LBBDD) have reached an agreement over the siting of the proposed 1000 MW combined cycle gas turbine (CCGT) power station at Barking Reach.

LBBDD has made available a piece of its own land and, together with Thames Power, has secured land options close to Dagenham's Ford car plant and the former Dagenham Dock to ensure an early start for construction of the station — one of the first of a new generation of stations designed to reduce environmental impact and increase efficiency.

Thermal efficiency of the process is high — at nearly 50% for combined cycle operation — compared with 38% for a conventional coal-fired power station. Waste gases from combustion will be discharged through chimneys, having first been treated for NO<sub>x</sub> removal.

The Barking Reach Development Scheme covers 800 acres on a two-mile stretch of the Thames riverfront and includes green space, wetlands and nature reserves as well as space for possible future housing and industrial and leisure facilities. Thames Power is currently negotiating with electricity companies for long-term supply contracts, to become effective in 1994 when the power station is commis-

sioned. Thames Power and LLBD, who are sharing the land option fees equally, have until June 1991 to exercise the option.

## Home energy labelling

TONY BALDRY, Junior Environment Minister, has welcomed the recent launches of two independent home energy labelling schemes.

Based on the Building Research Establishment's BREDEM computer model for assessing energy requirements for dwellings, the National Energy Foundation's Home Energy Rating Scheme gives properties a points rating from 0 to 10, while the MVM Consultancy's Starpoint scheme uses a one-to-five star rating.

The aim of the scheme is to encourage the building industry to raise public awareness of energy efficiency.

## CIS paper

DUE TO limitations of space, we are unable to include a report on Malcolm Edwards' speech at the Coal Industries Society luncheon in January.

However, the full text of the paper appears as an insert in this month's issue of *Energy World*.

## Nature reserve at Drax



Sheep may safely graze — and trees and crops flourish — on what was once a derelict army camp and is now the ash disposal site for National Power's vast Drax power station in Yorkshire.

The Barlow land reclamation scheme, which has been 17 years in the making, is entirely man-made, with stone-filled drains, dykes and lagoons providing irrigation. A one-metre-thick carpet of dry pulverised ash — a by-product of the power station — is damped and conveyed by conveyer belts to the disposal site. Huge bulldozers shape the ash which is then covered by topsoil from the original site. Today Barlow has 200 acres of green farmland, supporting sheep and cattle, thousands of trees and a nature reserve.



## Message from the President

LAST YEAR for the first time for many years The Institute of Energy holds its Annual General Meeting (AGM) away from London. This AGM was associated with a conference and a social weekend. The event, held in Scarborough, was undoubtedly a social success greatly enjoyed by those attending.

This year it has been decided to mount a significant conference and exhibition in London and to follow this with the AGM including the presentation of awards, followed on the same evening with a dinner dance.

I would urge members and their partners to take this valuable opportunity to meet colleagues in a pleasant and informal atmosphere by either taking part in all or a selection of events in the programme.\*

**D M Willis**  
President

\*For further information please refer to the insert enclosed with this issue.

## Sainsbury student prize awarded



Pictured left is Peter Ibbotson, Director of Construction, J Sainsbury plc presenting the Institute of Energy/J Sainsbury prize to Kevin Smith (right), at a recent meeting of the London and Home Counties branch. The prize was awarded for Kevin's work while a student at the South Bank Polytechnic.

## Institute of Materials in 1992

MEMBERS of The Institute of Metals voted overwhelmingly in favour of the formation of an Institute of Materials at their general meeting held in October 1990.

Although the Institute of Ceramics and the Plastics and Rubber Institute, with whom The Institute of Metals had been discussing a merger for the last two and a half years, had so far failed to achieve the required 75% vote of approval from their members, The Institute of Metals very much hoped that they would still be able to join with it, on the terms already agreed, whenever they were able to achieve the required majority.

The Institute of Metals Resolutions had now been passed to the Privy Council for its consideration and approval, providing the legal framework for an Institute of Materials in January 1992.

## Fellow retires

TOM SMITH (Fellow) recently retired from The Steensen Varming Mulcahy Partnership, engineering services consultants.

Mr Smith headed the London-based practice when it was established in 1957, along with colleague Poul Hansen, who shared Mr Smith's retirement reception in the Clore Gallery, at the Tate in London.

Tom Smith, who until recently was Chairman of the Association of Consulting Engineers, will be CIBSE President as from April this year. He will continue as consultant to the Partnership until 1995.

## SPS-91 Contest

IN ORDER to promote solar power satellites, and to contribute to space education, the Société des Electriciens, organisers of the 2nd International Symposium on Power from Space (SPS-91) has set up an international contest for young people under 25, entitled 'Power from Space'.

The contest involves the creation of an eight page comic strip about solar power satellites.

Details are available from SEE-SPS-91, 48, rue de la Procession, 75724 Paris Cedex 15, France.

## Institution merger close

THE COUNCIL of the Institution of Electrical Engineers (IEE) have approved a document proposing a merger on 1 October 1991 with the Institution of Production Engineers (IProdE). Pending similar approval from the IProdE Council, the proposal will be voted on by corporate members of the Institutions in May.

## Retired CEng Association

RETIRED Chartered Engineers in the Worthing area are well served by the Retired Chartered Engineers Association (RCEA).

The association provides social activities for its members in the form of talks and visits, which aim to keep pace with developments in engineering technology.

RCEA hold an AGM, Annual Dinner, and the annual Cooch Memorial Lecture, as well as organising summer outings for members and their families.

Newly retired engineers who are interested should telephone 0903 201008.

## Caleb Brett Award

THE INSTITUTE of Energy is pleased to announce a new award in 1991, The Caleb Brett Award.

Caleb Brett, a division of Inchcape Inspection and Testing Services, will present the award for the best paper on commercially-utilised liquid fuels or lubricants.

The terms of the award include:

The award shall be known as the Caleb Brett Award of the Institute of Energy sponsored by Inchcape Inspection and Testing Services, Caleb Brett Division.

It will be awarded to the author or authors of the best paper on Commercially

Utilised Liquid Fuels or Lubricants. The field includes the production of the liquids from raw materials, their properties, their handling and utilisation.

The selection will be made each year by the end of March from the author, or authors of papers presented in the Institutes publications for the preceding year.

A generous monetary award will be paid by Caleb Brett.

As with all the Institute awards the selection body will consist of three members of the Publications and Conferences committee and will report to the latter.

## Can we afford to waste waste?

FELLOW of the Institute, Byrom Lees, is author of a report on waste incineration published by the National Society for Clean Air (NSCA) in December 1990.

Mr Lees makes the case for developing incineration — not generally a popular option — as the best environmental solution for waste disposal.

The report claims the global warming potential of methane from UK landfill sites equals that

of CO<sub>2</sub> from transport.

New pollution abatement technology combined with the potential for energy generation and recycling makes incineration look increasingly attractive, argues Mr Lees.

*Can We Afford to Waste Municipal Waste?* is available from NSCA, 136 North Street, Brighton BN1 1RG. Price £5 inc p&p.



*Obituary*

**W V Battock**

WHALLEY VOWE BATT-COCK (Fellow) born in 1913, died at the beginning of November after a short illness. He was an accomplished engineer who made many contributions to advanced coal utilisation technologies.

Whalley joined the staff of the British Coal Utilisation Research Association (BCURA) at Leatherhead in 1947 principally to lead an R&D programme on coal firing for gas turbines. His background included an MA in Engineering Sciences from Cambridge, an understanding of gas turbine technology derived from many years experience in the Engine Division of the Bristol Aeroplane Company, and an appreciation of how test equipment should be designed to match specific process requirements. This quickly enabled BCURA to make a worthwhile contribution to the activities in coal-fired gas turbine development, and to earn the respect of organisations both at home and overseas.

In 1956 he became the chief engineer at BCURA, thus applying his talents to a wider range of its activities. His consequent involvement in some of the more mundane aspects of engineering did not, however, prevent him from participating in the development work on a number of advanced gasification and combustion projects.

After his early retirement for health reasons in 1966, he continued his association with BCURA as a consultant. During the next five years he was involved in the work on combustion of coal for MHD power generation, and in the pioneering work on pressurised fluidised bed combustion (PFBC) of coal.

His contributions continued over the period 1972-84, when the Leatherhead laboratory was a self-financing contract research organisation. The engineering capabilities that he already demonstrated up to that time contributed to the success of the Leatherhead team in being chosen to carry out some of the larger overseas contracts in the fields of pressurised fluidised bed combustion and gasification.

He was involved in many of the aspects of the design and test work on the Grimethorpe PFBC programme which was carried

out under the auspices of the International Energy Agency, and particularly in the detailed preparation of the case for installing a gas turbine on the Grimethorpe facility — a development which is at last about to take place.

After the closure of the Leatherhead laboratory, the senior staff formed a consultancy group, and Whalley participated in a number of their assignments in the fields of fluidised bed combustion and gasification.

Whalley, who joined the Institute in 1962, was a gentleman in the best sense of the word and he commanded great respect from all those with whom he came into contact. During recent years he devoted much of his time to village affairs, and in particular to the Eversholt Village Charity of which he was chairman. His wife, Beryl, died seven years ago. He is survived by a son and daughter and his sister Hester.

*Raymond Hoy*

*John Stanton*

*Alan Roberts*

**New directors**

TWO members of The Institute of Energy have been promoted at Rendel Hancox, the Glasgow-based mechanical, electrical and energy engineering consultants in the High-Point group.

Chris Boyd (Associate Member) has been appointed senior assistant director of Building Services, and Robert Loudon (Member), assistant director in charge of the Edinburgh office.

Mr Loudon joined the Institute in 1981, Mr Boyd in 1988.

**Award presentation**

KEVIN F POMFRET and John D Waddington received their Royal Society Esso Energy Award from the Society's President, Lord Porter in November.

Mr Pomfret and Mr Waddington, both of whom work at the British Gas Midlands Research Station, won the award for their work on developments and exploitation of gas-fired rapid heating furnaces for the industrial metal reheating market. It has been estimated that the energy savings to date resulting from the application of this technology are in excess of 18 million therms.

**New members**

*Fellow*

**Peter Edward Browne**, Gilbert-CMPS Engineers, Australia (*transfer*)

**Robert Paul Osmond**, NIFES Consulting Group, Birmingham (*transfer*)

*Member*

**Stephen Granville Barlow**, London Borough of Croydon (*transfer*)

**Donald Francis Carey**  
**David Anthony Gatehouse**, British Steel, West Glamorgan (*transfer*)

**Richard Michael Hansen**, Wallace Whittle & Partners, London (*transfer*)

**Michael Kelly**, The Sinnett Partnership, London

**Kwok-Lun Alain Lam**, Environmental Protection Dept, Hong Kong

**Kevin John Lomas**, Leicester Polytechnic

**Ian Christopher Parmee**, Knight Piesold & Partners, Kent

**Paul John Richardson**, Martin Clowes Associates, Surrey (*transfer*)

**Martin Roberts**, The Dyer Warner Partnership, Leics

**David Stuart Turner**, Davy McKee (Stockton) Ltd, Cleveland

**Robert Lewis Wiles**, Ruston Gas Turbines, Lincoln

**John Anthony Clifford Woodley**, Georgia Power Company, USA (*transfer*)

*Associate Member*

**William Crockett**, Total Oil Marine Plc, Aberdeen

*Graduate*

**Christopher Mark Davison**, Midlands Research Station, Solihull

**Richard Martin Everest**, British Gas (Southern), Reading

*Student*

**Yvonne Anderson**, Napier Polytechnic, Edinburgh

**Suryati Balu**, Polytechnic of Wales, Mid Glamorgan

**Peter Brand**, University of Newcastle-upon-Tyne

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CONCERN is growing about the levels of emission of carbon dioxide because it is one of the 'greenhouse gases' thought likely to cause global warming, which may become significant over the coming decades. The UK emits about 3% of the total global emission of CO<sub>2</sub>, the principal source of emission being power stations (33%), direct use of fossil fuels in industry (17%), the domestic sector (17%), and in transport (21%).

The pros and cons for reducing UK CO<sub>2</sub> emissions by substituting natural gas for solid and liquid fuels, by producing heat and power using biomass and waste products and by the wider use of renewable energy resources, such as wind power and nuclear energy, are discussed. CO<sub>2</sub> emissions can also be reduced by using less energy, both by improving the efficiency of energy conversion in fossil fuels — particularly to electricity — and by improving the efficiency of domestic energy use in industry and in transport.

A mix of the above has been suggested by a Working Party of the Watt Committee on Energy to reduce UK CO<sub>2</sub> emissions in the short term while international agreements are sought on the need for and ways of reducing global emissions. The aim is to achieve a significant reduction of CO<sub>2</sub> (more than 20%) without causing further environmental problems or undue technical or economic difficulties.

The present mean global concentration of carbon dioxide in the atmosphere is about 280 parts per million by volume. This CO<sub>2</sub> is important to plant life, particularly to the

# An overview of CO<sub>2</sub> emissions

by Dr G G Thurlow CEng PhD FIMechE FinstE\*

**In the following article Dr Thurlow examines some of the responses to reducing CO<sub>2</sub> emissions, in particular those put forward by the Watt Committee's Working Party on Technological Responses to the Greenhouse Effect. Leaving aside the complex arguments surrounding the connections between man-made CO<sub>2</sub> and global warming, he concludes that any attempt to curb UK emissions would be ineffective without worldwide co-operation.**

process of photosynthesis; previously it was considered merely as a useful minor constituent of our atmosphere. It is only in recent years that the role of CO<sub>2</sub> as the major gas responsible for reflecting back heat towards the Earth has been thought significant. The greenhouse effect of CO<sub>2</sub> together with water vapour, methane, nitrous oxide and CFCs is naturally responsible for controlling the mean global temperature at around 15°C, which would be -18°C were it not for this gas layer stopping heat from the Earth's surface escaping into space.

Now causing concern is the fact that, due to human influence (and particularly by the burning of fuels containing carbon), the CO<sub>2</sub>

concentration in the atmosphere has been rising since around 1800 and is still rising at an accelerating rate. Mathematical models suggest that this, plus increases in the other greenhouse gases, will lead to a rise in mean global temperature which might affect the environment significantly within a matter of decades.

It is not intended in this short article to take sides in the arguments about the connection between man-induced CO<sub>2</sub> emissions and global temperature or whether an increase in CO<sub>2</sub> concentrations would have benefits in increasing plant growth. Most people seem to agree that, until more is known about the likely outcome, it is sensible to curb CO<sub>2</sub> emissions — although the determination with which this should be applied is a matter of debate.

Most important, according to meteorologists, is the average global concentration of CO<sub>2</sub>. The benefits to individual countries obtained by reducing their CO<sub>2</sub> emissions are only significant if their efforts contribute to the total global reduction. Conversely, any detrimental effect of a large amount of CO<sub>2</sub> emission on one location is measured against the extent to which the emission adds to the global total.

## The UK position

The UK emits only about 3% of the total emission of CO<sub>2</sub>, corresponding to about 1½% of the total effect of man-emitted greenhouse gases. It would therefore be masochistic for this country to take painful measures to reduce the amount of CO<sub>2</sub> it emits except in the context of a worldwide, or nearly worldwide,

## The author

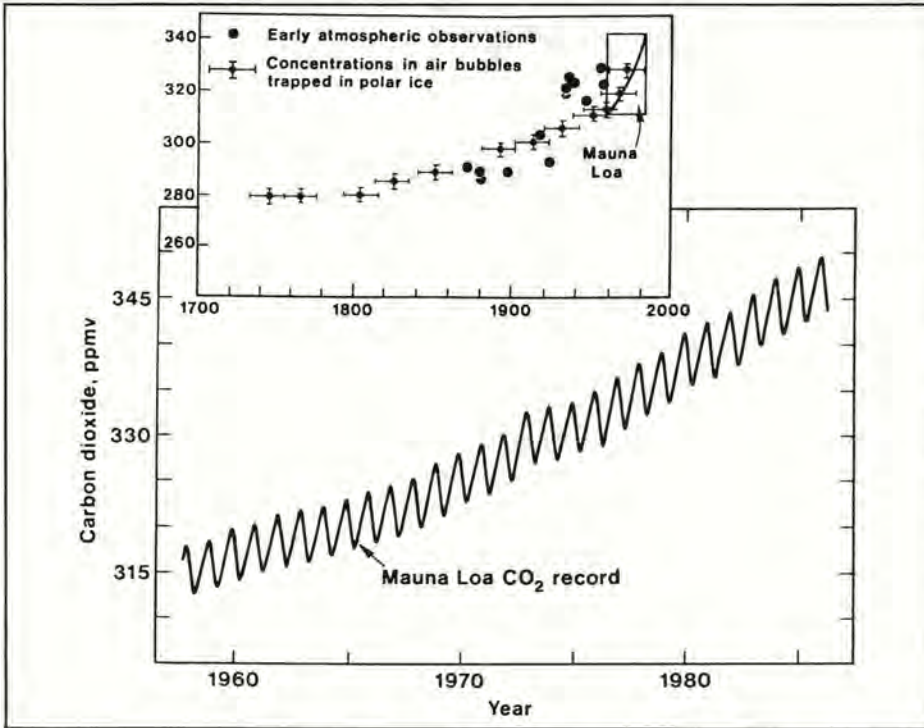
A graduate in Mechanical Engineering from the University of Bristol, George Thurlow was awarded a PhD from that university in 1953. After spending 24 years with the British Coal Utilisation Research Association and 15 years with the NCB (now British Coal), mostly at the Coal Research Establishment, Stoke Orchard — where his main interests were in fluidised combustion, coal gasification and the production of transport fuels from coal — Dr Thurlow retired in 1986.

Since then, he has carried out consultancy work for the EEC Energy Directorate and others, is Honorary Secretary of the Energy Industries Club, and has been Chairman of a Working Party set up by the Watt Committee to consider possible technological responses to the greenhouse



effect. He was President of the Institute in 1984-85 and is still a member of the Membership Committee.

\*Hon Sec, Energy Industries Club  
Past President, Institute of Energy



**Fig 1: The accelerating rise in CO<sub>2</sub> since 1800 demonstrated by measurements of atmospheric CO<sub>2</sub> concentrations made at Mauna Loa, Hawaii, since 1958 and (inset) concentrations derived from earlier atmospheric and ice-core data.**

joint effort. This does not mean that Britain cannot help to mount this global effort by demonstrating what can realistically be achieved.

Almost all British CO<sub>2</sub> emission comes from the combustion of coal, oil (including petrol and diesel) and gas. Electricity generation accounts for about a third of the UK total, while the direct use of fossil fuels in industry accounts for 17% of the total emission compared with 14% in the domestic sector. Transport, mainly road vehicles, contributes a further 21% at present but, while emissions from the stationary use of fuels is anticipated to increase only slowly in the UK, even without active measures to limit CO<sub>2</sub> emissions, road vehicle emission is expected to rise steeply.

The latest available figures (1988) show that about 43% of the total UK emission of CO<sub>2</sub> arises from the combustion of solid fuels compared with 37% from oil and 19% from natural gas.

## Reducing CO<sub>2</sub> emissions

Energy release from fossil fuels is obtained mainly from the combustion of carbon and hydrogen. Thus, one can reduce the amount of CO<sub>2</sub> emitted from the same heat release by burning fossil fuels with the highest ratio of hydrogen to carbon. Natural gas, for the same energy release, only emits about 60% of the CO<sub>2</sub> emitted by coal. This provides an added incentive to use natural gas in the UK, where it is already commercially attractive — particularly as it is possible to build, relatively cheaply and quickly, highly efficient power generation units burning natural gas. However, a switch to this premium fuel (if extended worldwide) could lead the UK to becoming dependent on distant, and increasingly expensive, sources of

supply within the next decade or two.

Natural and man-produced organic waste is often burned or — what is worse from the aspect of the greenhouse effect — allowed to convert to methane, a gas which, weight for weight, has an effect at least an order of magnitude more severe than CO<sub>2</sub>. Burning these wastes in steam-raising plant, a proven technology, would replace the emissions produced by burning other fuels. It is possible that 20 million tonnes of coal or its equivalent could be replaced by these waste and biofuels, given the time required to build the necessary plant and the infrastructure to feed them.

Another way to reduce CO<sub>2</sub> emission for the same energy output is to use more non-fossil fuels. Renewable energy sources such as wave, tide, solar and, particularly, wind power will and should be developed further. But none of these sources appear capable of more than a few per cent. Nuclear power has the potential to replace a large part of fossil fuel generation and may well be required to do this in the absence of new, as yet unthought of technology once world reserves of gas and oil become short. While there are strong forces against the use of more nuclear power in the immediate future, it may prove very shortsighted not to maintain effort to develop safer and more acceptable nuclear power systems.

It looks as if the UK will be dependent on fossil fuel for much of its energy needs at least for the foreseeable future. If one can reduce these needs, however, we shall need less fuel and therefore release less CO<sub>2</sub>. Mention has already been made of improving the conversion of fossil fuels to electricity. The possible improvements using natural gas are also being applied to coal and other solid fuel. This new technology will be crucial as the use of solid fuel grows in the developing world as

well as in the developed countries, including the UK, as other fuel sources become less attractive.

Even with these new technologies, however, more than half the energy in the primary fuel is not converted to electricity and there must be continuing pressure to make use of this heat in combined heat and power schemes in industry, for commercial use and in district heating.

In time, methods for removing CO<sub>2</sub> from flue gas will be developed and, what is more difficult, storing it in a form and place where it will not leak into the atmosphere. Much effort will be needed before reliable schemes at an acceptable cost will be available. In parallel to this is the potential for using less energy by using it more efficiently. All sectors of the British public have been exhorted to save energy since the last world war initially as fuel was in short supply, later to reduce costs and now, to reduce CO<sub>2</sub> emission. Saving energy has been well aired over the years in *Energy World*. That there is still plenty of scope for improvement indicates the difficulties ahead in trying to reduce CO<sub>2</sub> emission effectively.

The contribution of the woodlands in Britain as a sink for carbon dioxide is small. Even if we doubled our present woodland area, making approximately 20% of the total land mass wooded, the trees would only take up about 2.5% of the carbon now put into the atmosphere by the burning of fossil fuels. Only growing trees take up carbon, so that to maintain a sink it would be necessary to remove up to 4 million tonnes of carbon, as mature trees, each year and replace them with young trees. Much of this timber would be burnt in steam-generating stations to replace coal or gas, or converted into ethanol as a transport fuel.

## Helping other countries

It is predicted that there will be increased use of fossil fuels — particularly coal, often of low quality — in the developing countries; it would be presumptuous to expect them to restrict attempts to raise their standard of living because of greenhouse effect predictions. Developed countries can help by ensuring that this new energy production is achieved at a much higher and sustained level of efficiency than is often now the case. Not only is it necessary to make available the best technology, so long as it is well proven, but also to provide essential training and management to the local engineers.

The destruction of the tropical rainforests has been described elsewhere as a major ecological disaster. However, rainforest preservation depends on far wider issues than the greenhouse effect alone. Even so, the CO<sub>2</sub> released by the burning of felled trees has been responsible for about a quarter of all global emissions over recent years. The need for international effort is imperative.

## What happens now?

Many countries have agreed that a realistic short-term target for restricting the emission of the greenhouse gases, including CO<sub>2</sub>, is to stabilise emission rates at their present (1990)

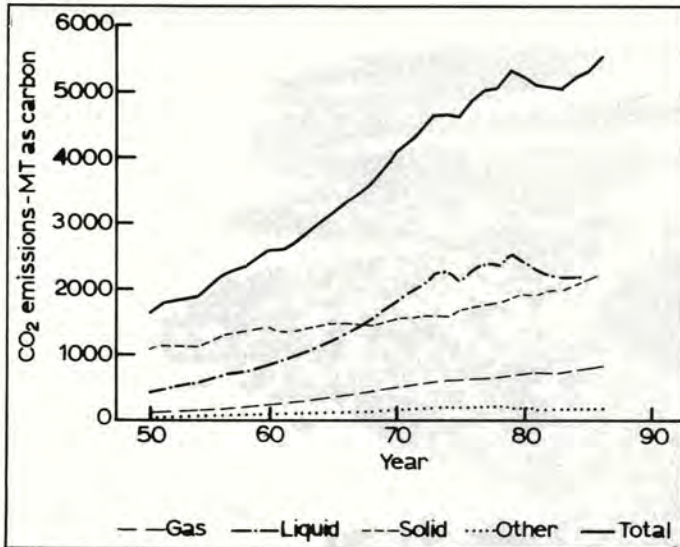


Fig 2: Total global emissions of CO<sub>2</sub> (expressed as carbon).

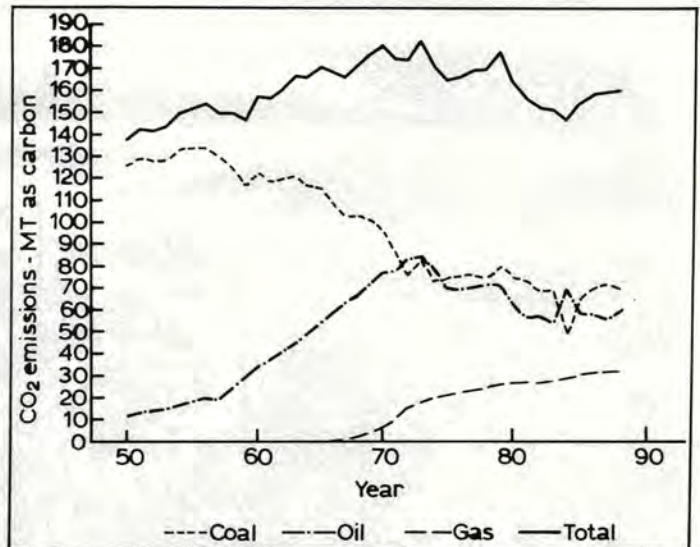


Fig 3: UK emissions of CO<sub>2</sub> (expressed as carbon).

**Table 1: Measures proposed by the Watt Committee Working Party for reducing CO<sub>2</sub> emission in the UK**

- Short list of short-term greenhouse measures
- High efficiency natural gas-fired gas turbine combined cycle power generation plant
- Natural gas-fired gas turbine or gas engine combined heat and power in industry, the public and commercial sectors
- The promotion of wind energy
- Combustion of non-recycleable waste, refuse and biomass with energy recovery wherever possible
- Energy saving in public and commercial buildings and the domestic sector. In particular by:
  - thermal insulation and draught-proofing
  - space heating (efficiency, fuel type, CHP, controls)
  - more efficient electrical appliances
  - low energy lighting and lighting controls
- The promotion of smaller, more efficient cars
- Increasing the area of woodlands, especially combined with greater use of wood, including as a fuel
- For listed CFCs:
  - adopt urgent measures to phase out manufacture worldwide
  - recover CFCs from plant and appliances so that they may be recycled or rendered harmless

substitute substances with a much smaller greenhouse potential than the listed CFCs

Work with developing countries: to formulate and implement global policies for forestry and agriculture to help improve the efficiency of energy conversion and utilisation

Short list of longer-term research and development topics

- Clean and high efficiency use of coal in electricity generation
- CO<sub>2</sub> removal from flue gas
- Nuclear power
- New transport fuels and methods of transport

levels by early next century. Many European countries suggest that this can be achieved by 2000, while the British government argues that 2005 is a more realistic date. As the rate of emission of CO<sub>2</sub> is expected to rise by about 20% over the next decade unless specific actions are taken, ways have to be found of reducing emissions by about 20% from their present values in order to stand still.

The Watt Committee on Energy's Working Party on Technological Responses to the Greenhouse Effect has proposed a basket of

measures to achieve this reduction without imposing an unacceptable financial burden or leading to further environmental or social problems.<sup>1</sup> The range of measures selected by the Watt Committee are listed in Table 1, which also lists areas where research and development is now needed if the reduction in CO<sub>2</sub> emission is to be maintained into the next century.

There is clearly going to be a long period of discussions before any international agreement is reached. Even then, it is doubtful that such agreements will result in a marked reduction in global CO<sub>2</sub> emission. The one certainty is that there will still be large amounts of CO<sub>2</sub> emitted into the atmosphere well into the foreseeable future. Whether this will result in an increase in temperature and what effect this will have region by region remains to be seen. Meanwhile, perhaps the most we can hope for is enough time to learn how best we can cope with the changes in store. □

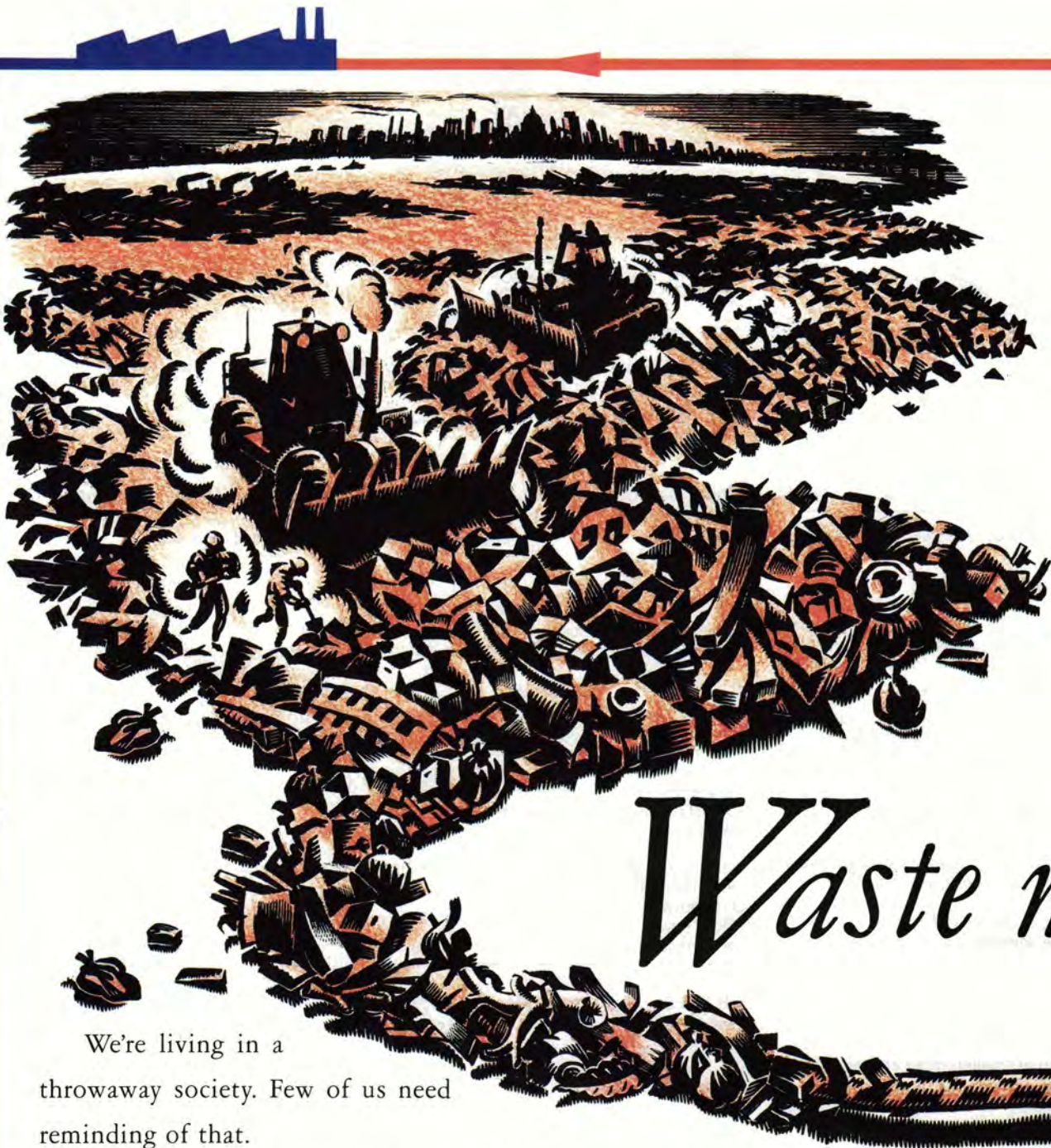
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- 1 Thurlow, G G (Ed) 1990. *Technological Responses to the Greenhouse Effect*, published on behalf of the Watt Committee on Energy, Elsevier Applied Science, 98pp.

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# Waste not.

We're living in a throwaway society. Few of us need reminding of that.

But do you realise just how much rubbish every one of us in the UK produces in a year?

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Add to that the waste from offices and factories and you have around 130 million tonnes of rubbish to dispose of.

Most of it gets ploughed into the ground on landfill sites.

There are about 3500 of these. And those

near towns and cities will fill up sooner or later. Tipping refuse further afield may sound like a reasonable alternative.

Until you consider the cost, both in terms of transporting the waste and what dumping would do to the local environment. Recycling waste is clearly part of the answer. But another important approach is the one

already taken by other European countries.

They have started to burn refuse, using the energy produced to generate electricity.

Some of the local authorities in this country are already following their example.

Others may be burning waste, but only to dispose of it. Could they be producing electricity as well?

That's a question we would be able to answer. At National Power, developing alternative ways of producing energy is very much on our list of priorities.

As well as seeking involvement in waste-to-energy projects, we're also looking at renewable forms of energy such as wind power.

Of course, at present the vast majority of electricity is produced by more conventional means, and a more conventional solution may well be the answer to your energy needs.

A joint venture, say, to build your very own power station.

That may not sound very orthodox, but developed as a Combined Heat and Power scheme, the idea is far from new.

And it can be highly cost-effective.

That's because generating electricity generally produces steam and this can be used for heating or to power machinery.

Then again, if you're a one megawatt user, we may suggest that your best option is simply to buy your electricity, competitively priced, direct from us.

Coming up with solutions, conventional or otherwise, is all part of day-to-day business at National Power.

As the largest producer of electricity in England and Wales, we certainly have the necessary skills and know-how.

We own 40 power stations with a total generating capacity of nearly 30,000 megawatts. Many of our people have over 20 years of experience in the power industry.

During that time there have been many changes. Producing electricity from waste could well be another change for the better.

If you would like any further information, please write to Roger King, Waste Management, Sudbury House, National Power PLC, 15 Newgate Street, London EC1A 7AU.



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# Want not.





# The Costs of Flue Gas Desulphurisation

by Dr Anupam Sanyal

THE TOPIC and the timing of this seminar could not have been chosen more appropriately since the Department of Environment's Consultation Paper on the Implementation of the EEC Directive on Large Combustion Plants was published the previous day, on 18 September 1990.

Attended by over 150 delegates from five countries, the seminar pioneered a forum for professional discussion on the costs of flue gas desulphurisation (FGD), which is currently uppermost in the mind of utilities and industries alike.

Mr Doug Willis, President of the Institute, inaugurated the seminar and invited Professor Dr Eng Klaus Hein of Delft University, the Netherlands, to give the opening address. Professor Hein, an international authority in the field of combustion and environment, set the scene by reviewing the situation in Europe. In order to reduce the adverse effects of sulphur dioxide emission on flora and fauna, and to minimise the probability of smog formation, various countries have taken legislative action to specify percentage removal requirement, and to limit the sulphur content of coal and oil. The EEC directive for emission targets is given in Table 1.

Table 1: Current SO<sub>2</sub> emission targets

Country	Reduction %*	Date
Austria	75-80	1995
Belgium	40	1995
Canada	30	1995
Denmark**	50	1995
Finland	50	1990s
France	65	1995
Germany	70	1995
Italy**	30	not known
Netherlands	70	2000
Sweden	65	1995
UK	60	2003

\* compared with 1980 emissions

\*\* applies only to power plants or complexes with 1980 emissions over 300 t.

As an example, the German regulation of 1983 stipulated a reduction by more than 85% in 1989 from the 1982 level for fossil-fuel-fired power stations. Chances of removal of sulphur-bearing minerals from coal prior to combustion are very limited. Besides, sulphur is present in the coal itself, which produces sulphur dioxide during combustion. The only applicable option is its removal as a post-combustion

measure. The schemes for removal, particularly in Europe, fall under five categories, of which the wet limestone gypsum process is the popular choice.

In the EEC, Germany is the only country where flue gas desulphurisation plants have been under operation in all power stations of 300 MW thermal and larger. Depending on the capacity and location, the investment costs for new installations during the 1985-8 period ranged from 50 to 100 million DM per unit for retrofits. The large variation in the cost reflects the variety of local boundary conditions. Interestingly enough however, the specific investment cost for the majority of the large units indicates an average of about 150 DM/kW. The total retrofit cost for 38,000 MWe completed by July amounted to approximately 15 billion DM, with an annual operating cost of the order of 3.5 billion DM. Based on an annual electricity production of approximately 180 TWh, the average increase of electricity generation costs on account of flue gas desulphurisation works out to about 0.02 DM (0.7p/kWh).

Jan Vernon of KPMG Peat Marwick Management Consultants in her talk 'Sulphur Control: The Regulatory Framework' outlined the current status of legislation on sulphur

emissions at national and international levels, and assessed the potential for change over the next few years. She examined the impact of different types of legislation on the market for sulphur control, with particular emphasis on the demand, availability and potential costs of low sulphur coals. In her opinion there is to be sufficient supply of such coals in the long term, with possibility of some near-term shortages, until transport and supply systems can meet the demand. The increase in demand may lead to a price premium for low sulphur coal. The legislation may also promote the development of advanced combustion technologies.

John Cooper of National Power then outlined the relative costs of various FGD systems carried by the then CEGB on the eve of the Drax enquiry. Their study indicated that for a station of 4,000 MWe units, limestone/gypsum was the most economic option. (It is to be noted, however, that the normalised lifetime cost of sulphur removal becomes favourable to the wet limestone/gypsum process as a result of the high cost differential between limestone and lime used for the semi-dry process. The economics would be more favourable for the latter system in medium to large size units if the cost differential were reduced.)

Bill Kyte was not in a position to talk about the costs as advised by his employer. He outlined PowerGen's strategy for meeting its requirement of SO<sub>2</sub> reduction under the EEC directive. FGD plants, fuel substitution with gas and low sulphur coal, as well as construction of combined cycle gas turbines, are the options chosen by PowerGen.

Mike Cooke of British Coal outlined the costs of lime spray dry and alkali scrubbing systems for industrial scale plants. Based on a 62.5 MW thermal input plant, firing coal having 1.5% sulphur for a removal efficiency of 35% and a load factor of 48%, the installation and operation of a new FGD equipment will increase the steam cost by 12% for a spray dry system compared to 20% on alkali scrubber. In terms of sulphur removal, every tonne of sulphur removal would cost £2,000 for a spray-dry and £3,000 for an alkali-scrubbing system. The figures will change with the increase in the size of the plant.

The next three talks in the afternoon session chaired by Mike Tunnicliffe of the Inspectorate of Pollution were from the designer/operators from Europe for industrial and utility plants based on various systems currently in operation.

Erkki Valimaki of Tampella Power Industry of Finland presented a paper which examined the cost of desulphurisation applied to a coal-fired plant of 700 MW thermal, firing coal of

## The author



**Dr Anupam Sanyal is the Chief Fuel Technologist of Babcock Energy Limited and has the additional responsibility of advising Babcock on environmental control business systems.**

**A Fellow of the Institute, he is an ex-member of the Council and a member of International and Conferences & Publication Committees.**



SUPPLEMENT

# The Greenhouse Effect and Global Warming

by Sir John Mason CB DSc FRS

**A**TMOSPHERIC concentrations of greenhouse gases such as water vapour, carbon dioxide and methane affect the radiative heat balance and surface temperature of the Earth. On present trends, increases in CO<sub>2</sub> and the other greenhouse gases are together likely to approximate to a doubling of the present concentration of CO<sub>2</sub> by the year 2060.

The effects of such a perturbation on the global climate are estimated using large, complex computer models designed to simulate the present climate and its natural variations, and to predict future changes whether natural or man-made. Current best estimates, based on coupled atmosphere-ocean models, indicate that a doubling of CO<sub>2</sub> would produce an average global surface temperature rise of 2.5°C and a rise in sea level of 50 cm. However, the model predictions are sensitive to rather small changes in the properties of clouds and their influence on radiation, so that the treatment of these and other feedback mechanisms will have to be improved in order to reduce the uncertainties of current predictions and provide firmer scientific guidance for remedial action.

The oceans will almost certainly reduce and delay any global warming because of their large capacity to absorb heat and about half of the CO<sub>2</sub> emitted into the atmosphere. This may largely explain why it is not yet possible to detect a clear signal that can be confidently ascribed to greenhouse warming rather than to natural climate fluctuations.

## Introduction

The greenhouse gases, especially water vapour and carbon dioxide, play a crucial role in regulating the temperature of the Earth and its atmosphere. In the absence of these gases the average surface temperature would be -19°C instead of the present value of +15°C, and the Earth would be a frozen, lifeless planet. There is now concern that atmospheric temperatures will rise further, due to the steadily increasing concentration of CO<sub>2</sub> resulting largely from the burning of fossil fuels. The concentration is now 27% higher than that which prevailed before the industrial

**Based on the 1990 Robens Coal Science Lecture presented at the Royal Institution, London 5th November 1990**

revolution, and is increasing at 0.5% pa. It is expected to reach double the 1860 value during the second half of the next century. Recently we have become aware that other strongly absorbing gases, notably methane, nitrous oxide, ozone and chlorofluorocarbons (CFCs) are adding to the greenhouse warming and may, by the middle of the next century, contribute about half as much again as the increase in CO<sub>2</sub>.

Higher temperatures will be accompanied by changes in other climate parameters such as precipitation, cloudiness, soil moisture, snow cover and may, eventually, result in significant expansion of the oceans and melting of the mountain glaciers, and hence to a rise in sea level.

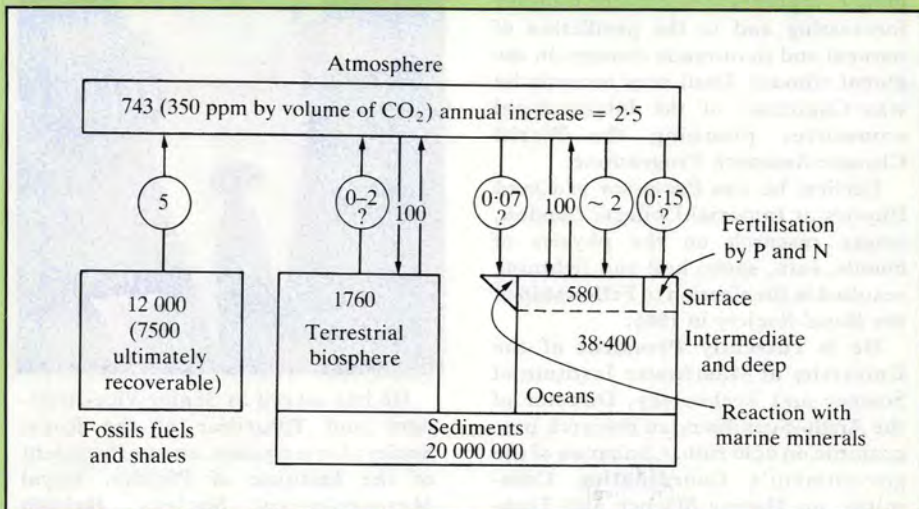
Although the climate changes and their economic and social effects are likely to vary seasonally, and geographically from region to region, and even from country to country, the

overall problem of man-induced climatic change is a global one, whose thorough study is beyond the resources of any one country. It follows that national research programmes should be planned largely as contributions to international projects, such as the World Climate Research Programme and the World Ocean Circulation Experiment, described by Mason (1987).

## Global budget of CO<sub>2</sub>

In order to estimate more accurately the future concentration of atmospheric CO<sub>2</sub>, it will be necessary to study and understand in more detail the complete carbon cycle. The problem is that partition of the added man-made CO<sub>2</sub> between the atmosphere, oceans and biosphere involves difficult estimates of small differences between large two-way fluxes between enormous reservoirs, as illustrated in Fig 1.

The total atmospheric reservoir of CO<sub>2</sub> is equivalent to 743 GtC (gigatonnes of carbon: 1 gigatonne = 10<sup>9</sup> = 1 billion tonnes) which is much smaller than 1760 GtC for the terrestrial biosphere, of which about 560 Gt is stored in trees and plants, and is tiny compared with the 39 000 Gt in the oceans. The atmospheric concentration is therefore susceptible to rather

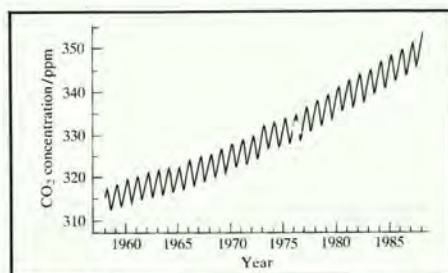


**Fig 1: Global carbon reservoirs and present natural and anthropogenic fluxes between reservoirs. Reservoir size in GtC (1GtC = 1 thousand million (10<sup>9</sup>) tonnes of carbon). Fluxes between reservoirs in GtC per year. Anthropogenic fluxes are circled (after Liss & Crane 1983).**



small changes in the fluxes between these reservoirs. The current rate of emission of CO<sub>2</sub> from the burning of fossil fuels is 5.4 GtC/yr, while the net emissions due to deforestation and changes in land use are estimated at 1.6 GtC/yr. These are small compared with the fluxes exchanged between the atmosphere and the Earth's surface, which exceed 200 GtC/yr. The atmosphere retains about 3.4 Gt (almost 50% of the emissions) leaving 3 Gt/yr to be taken up by the oceans. The net fixation of CO<sub>2</sub> by photosynthesis, largely by phytoplankton growing in the top 100 m or so, is about 100 GtC/yr, about the same as for the terrestrial biosphere. Most of this is released by respiration and returns to the atmosphere, but some is dissolved in the ocean and some is converted into inorganic carbon in the skeletons and faeces of zooplankton, and falls to the ocean floor.

Models of the ocean uptake suggest that it can accept about 1.8 GtC/yr, so that there is an apparent imbalance of about 1.6 GtC/yr. This is a measure of the uncertainty in current understanding of the global budget of atmospheric carbon dioxide. Either there are some, as yet unidentified, mechanisms for removing CO<sub>2</sub> from the atmosphere, or the amount of CO<sub>2</sub> released by tropical deforestation has been greatly overestimated, or our quantitative knowledge of the known mechanisms is unsatisfactory. Nevertheless, relatively minor adjustments in the world ocean circulation and chemistry are likely to affect significantly the amount of CO<sub>2</sub> added each year to the atmosphere, even if emissions are stabilised. In particular, ocean warming is likely to decrease the net uptake of CO<sub>2</sub> by sea water. Until this



**Fig 2: The increase in atmospheric concentrations of CO<sub>2</sub> since 1958, as measured at Mauna Loa, Hawaii.**

problem is resolved, predictions of the proportion of future emissions of CO<sub>2</sub> retained in the atmosphere will be subject to considerable uncertainty. However, an even larger uncertainty lies in the future global rate of increase of combustion of fossil fuels and wood, for which estimates range from less than 2% per annum to double this figure.

## CO<sub>2</sub> in the atmosphere

Analysis of air bubbles trapped in the deep interiors of glaciers reveals that the atmospheric concentration of CO<sub>2</sub> in the last Ice Age was about 210 ppmv. The value at the beginning of the industrial revolution is estimated at 275 ppm and to have increased by 15% over the following 100 years to reach 316 ppm in 1960. Since accurate and continuous measurements were started in 1958, the concentration has risen at an ever-increasing rate (see Fig 2), which is currently very nearly 0.5% pa. The present concentration of 354 ppm is 27% above the 1860 value. If the concentration were to continue to increase at the present rate

(0.5% pa), it would double its pre-industrial value by 2080, and double its present value by 2130 AD. However, it is likely that the increase will continue to accelerate, particularly if the world's population continues to increase at the current rate, and may reach double the present value, ie 700 ppm, in 80-130 years — depending on the future rate of burning fossil fuels and wood and the extent to which CO<sub>2</sub> is taken up and stored in the oceans and by trees and vegetation through photosynthesis.

## Radiation budget

The heat budget of the atmosphere and Earth is shown in Fig 3. Of the short-wave solar radiation incident on the top of the atmosphere (a global annual average of 340 W/m<sup>2</sup>) about 17% is reflected back to space by clouds, 8% is back-scattered by the air, and 6% reflected by the Earth's surface, to give a planetary albedo of 31%. About 19% is absorbed by water vapour, ozone and dust and about 4% by clouds as the radiation passes through the atmosphere, so only 46% is absorbed at the surface. This is transferred to the atmosphere as infrared radiation (a net 15 units where 100 units represents the incoming solar radiation), as sensible heat (7 units), leaving 24 units to evaporate water which later condenses to form clouds and a global annual average rainfall of 104 cm.

Considering now the balance of the long-wave radiation on the RHS of Fig 3, of the 115 units (390 W/m<sup>2</sup>) emitted by the Earth's surface, only nine are transmitted through the atmospheric window to space, the other 106 being absorbed by the atmosphere, mainly by water vapour, CO<sub>2</sub> and ozone. This absorption of the up-welling long-wave radiation, plus that from the incoming solar radiation (19 units), plus the sensible heat flux (7 units), total 132 units to which must be added a net contribution of (24+4-20=8) units from clouds. Of this total heat input of 140 units, the atmosphere emits 40 to space and 100 (340 W/m<sup>2</sup>) to the surface, the net long-wave radiative flux from the surface to the atmosphere being only 15 units. The net absorption of infrared radiation by the greenhouse gases is the difference between the 115 units of outgoing radiation from the Earth's surface and the 69 units emitted at the top of the atmosphere, ie 46 units or 154 W/m<sup>2</sup>.

In the absence of absorbing greenhouse gases (mainly water vapour and CO<sub>2</sub>), the equilibrium black-body surface temperature  $T_e$  of the planet, assuming it to have an albedo of  $\alpha=0.31$ , is given by the equation

$$4\pi a^2 \cdot \sigma T_e^4 = \pi a^2 S(1-\alpha)$$

or

$$T_e = \frac{S(1-\alpha)^{1/4}}{4\sigma} = 254^\circ\text{K}$$

where  $\sigma$  is Stefan's constant and  $S$  the solar constant and  $a$  the radius of the planet.

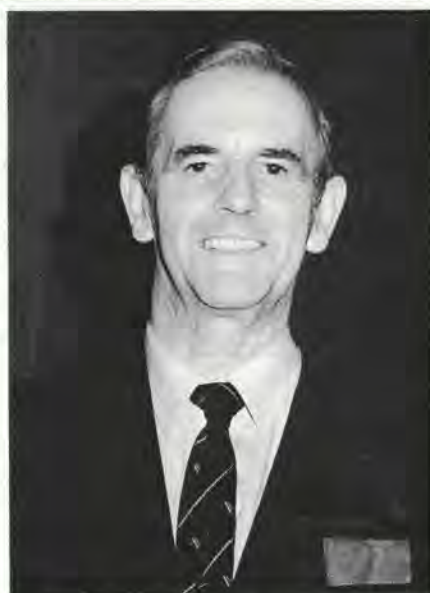
The intensity of the emitted radiation would be only 236 W/m<sup>2</sup> compared with the actual value of 390 W/m<sup>2</sup> which again implies that the combined contribution of the greenhouse gases is 154 W/m<sup>2</sup>. About 100 W/m<sup>2</sup> are calculated to come from water vapour and about 50 W/m<sup>2</sup> from CO<sub>2</sub>.

## The author

Sir John Mason CB DSc FRS, Director-General of the Meteorological Office from 1965 to 1983, has been much involved in the application of giant computers to worldwide weather forecasting and to the prediction of natural and man-made changes in the global climate. Until very recently he was Chairman of the international committee planning the World Climate Research Programme.

Earlier, he was Professor of Cloud Physics at Imperial College, London, where research on the physics of clouds, rain, snow, hail and lightning resulted in his election to Fellowship of the Royal Society in 1965.

He is currently President of the University of Manchester Institute of Science and Technology, Director of the Anglo-Scandinavian research programme on acid rain, Chairman of the government's Coordinating Committee on Marine Science and Technology, and Senior Adviser to the Imperial College Global Environment Research Centre.



He has served as Senior Vice-President and Treasurer of the Royal Society for ten years, and as President of the Institute of Physics, Royal Meteorological Society, British Association for the Advancement of Science, and the National Society for Clean Air.

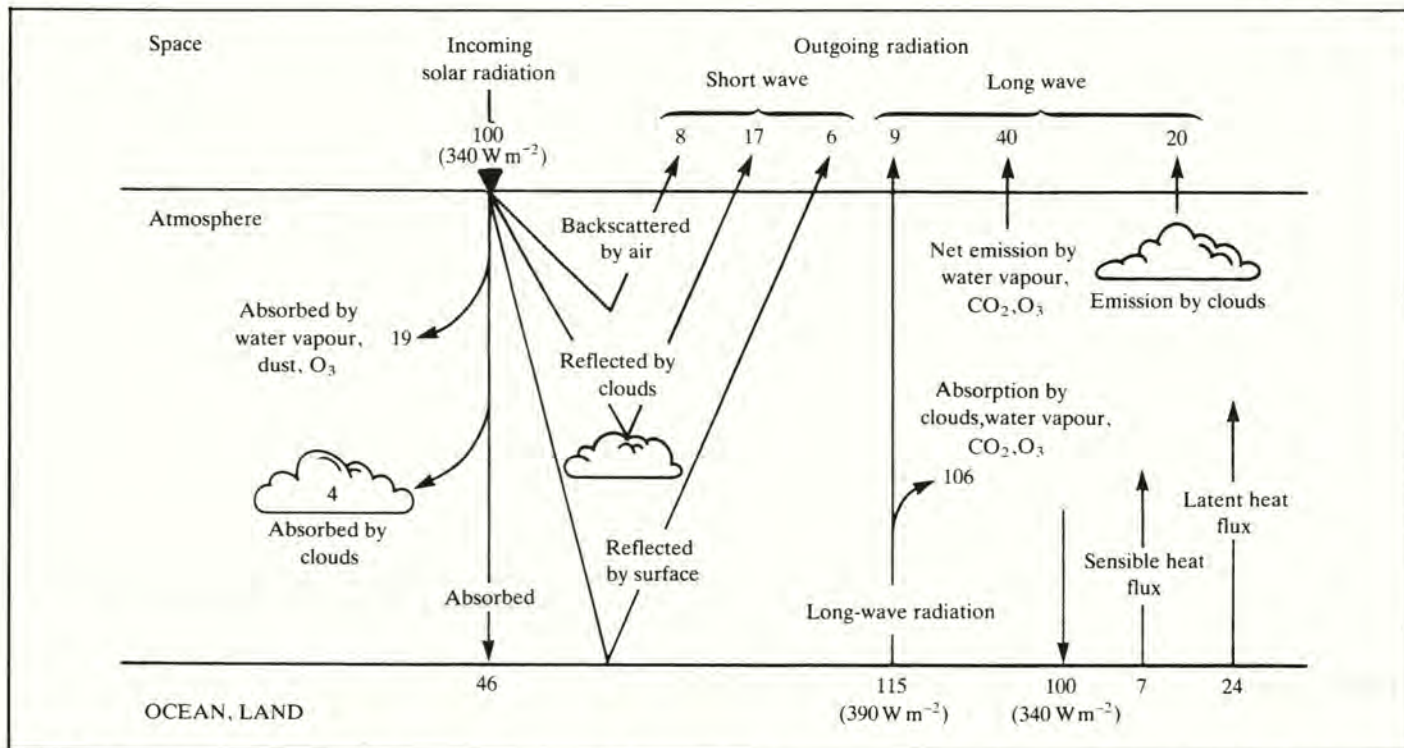


Fig 3: Radiation balance of the Earth: the numbers represent fluxes expressed as percentages of the global average incoming solar flux at the top of the atmosphere (100 units = 340 W m<sup>-2</sup>).

Both water vapour and CO<sub>2</sub> absorb infrared over a range of wavelengths; the relatively high concentrations of these two gases ensure that many of the spectral lines are saturated and any increase in absorption from an increase in their concentration is limited to the wings of the absorption lines. Thus, while the present concentration of CO<sub>2</sub> (354 ppmv) produces a downward atmospheric flux of 50 W/m<sup>2</sup>, a near doubling to 600 ppmv would increase the flux by only 3 W/m<sup>2</sup> and raise the surface temperature by only 0.9°K in the absence of feedback effects due to water vapour, clouds, ice, etc. The quantitative impact of the various feedback mechanisms in the global climate system can be estimated only from the results of large, complex models described below. However, a simple calculation for a climate system in thermal equilibrium indicates that the concomitant increase in water vapour would amplify the temperature rise due to CO<sub>2</sub> by a factor of 1.6 to 1.4°K. On the same basis, the enhancement of CO<sub>2</sub> since 1860 should have produced a warming of about 0.5°K.

**The other greenhouse gases**

Although water vapour and CO<sub>2</sub> are the main cause of the greenhouse effect, any gas that absorbs in the infrared will help to reduce the loss of terrestrial radiation to outer space. However, absorption by water vapour and CO<sub>2</sub> is so strong that other gases will contribute little unless they absorb at wavelengths, mainly from 8µm to 12µm (the atmospheric 'window'), where absorption by CO<sub>2</sub> and water is weak.

The most important trace gases that contribute significantly to the trapping of terrestrial radiation, despite their small concentrations, are methane, nitrous oxide (NO<sub>x</sub>) and the chlorofluorocarbons (CFCs), especially CCl<sub>3</sub>F (F11) and CCl<sub>2</sub>F<sub>2</sub> (F12). Methane concentrations are only about ½% of

those of CO<sub>2</sub>, but it is 21 times as effective molecule for molecule as an absorber of terrestrial radiation, while the CFCs are only one-millionth as abundant but 14000 times more effective than the same increase in CO<sub>2</sub>.

Methane, currently at 1750 ppbv, is increasing at about 1% annually, and is expected to double in about 70 years. Various sources of methane have been identified but not quantified. These include emissions from ruminants, rice paddies, waste disposal sites and oil recovery operations. Doubling methane would have about 15% of the warming effect of doubling CO<sub>2</sub>.

NO<sub>x</sub>, currently at 300 ppbv, is increasing at 0.25% per annum for largely unknown reasons. It is formed primarily as a product of bacterial denitrification but also in combustion processes. It is likely to increase by about 20% by 2060, contributing in the meantime about 4% to the total greenhouse warming.

Table 1 shows the present concentrations of CFCs in the atmosphere and their contributions to global warming to be about 0.2 W/m<sup>2</sup> or 12%. The trace gases combined now contribute about half as much again as CO<sub>2</sub> to greenhouse warming. Even if CFC emissions are reduced, the concentrations may continue to rise because F11 and F12 have atmospheric lifetimes of 80 and 140 years, respectively. If the Montreal Agreement to reduce emissions to 80% of 1986 levels from 1993, and to 50% from

1998 is fully implemented, CFCs are likely to contribute almost 10% to greenhouse warming in 2060.

A simple radiative calculation with no feedbacks would suggest that these greenhouse gases together should have produced a global warming of 0.7°K relative to 1765, but enhanced to 1.1°K by the concomitant increase in water vapour. A corresponding calculation of the present warming relative to 1900 gives 0.85°K very close to the best estimate obtained from advanced models of 0.9°K. However, this agreement is probably fortuitous as the simple calculations ignore all feedbacks except that due to water vapour.

The above estimate that the climate should have warmed by almost 1°K since 1900 prompts one to examine the observed average global temperature record which, as shown in Fig 4, indicates a rise of about 0.5°K over the last 90 years. However, it is unlikely that this can be attributed to the greenhouse effect for the following reasons:

- 0.3°K of the 0.5°K rise occurred between 1900 and 1940 when CO<sub>2</sub> was increasing at only 0.1% per annum, compared with the current rate of 0.5%.
- There was a small fall in temperature between 1940 and the mid 1960s, widely claimed by the media and some scientists in the 1970s to herald a new ice age!

Table 1: Global warming by greenhouse gases in 1990 relative to 1765

	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CFC <sub>11</sub>	CFC <sub>12</sub>	HCFC <sub>22</sub>	
Concentrations (1765)	279	790	285	0	0	0	
Concentration (1990)	354	1720	310	280	480	320	
	ppm	ppb	ppb	ppt	ppt	ppt	
Increased heat flux	1.5	0.42	0.10	0.06	0.14	0.08	Σ = 2.30 W/m <sup>2</sup>
% contributions	66	18	4		12		



- Despite the rather sharp rise during the last decade in average *global* air temperatures, this has not occurred in high latitudes, nor has there been any significant decrease in the ice cover, although all the models predict greatest greenhouse warming in the Arctic.

The timing of the fluctuations in the temperature record, and the fact that greenhouse warming is likely to be delayed for some decades because of the thermal inertia of the oceans strongly suggest that these are natural climatic functions. If we assume that this is indeed the case, we may use a coupled atmosphere-ocean model to estimate how long it will take for a greenhouse signal of, say, 0.5°K to be detectable. The only published account (Manabe 1990) of a coupled atmosphere-deep ocean model, in which CO<sub>2</sub> is allowed to increase at 1% per annum compound and so double in 70 years, predicts an average global temperature rise of 2-3°K, a rise of 0.5°K occurring after 20 years.

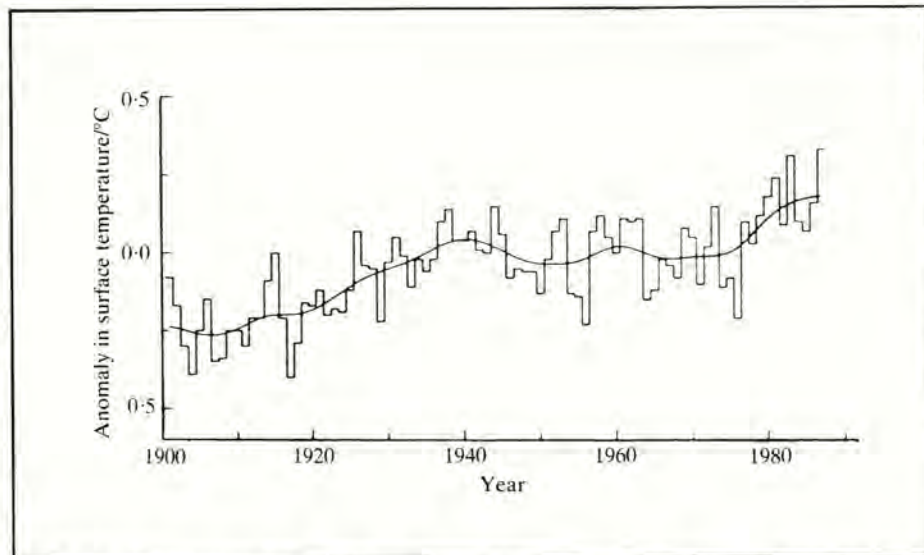
**Model simulations**

Changes in global and regional climates due to greenhouse gases will be small, slow and difficult to detect above natural fluctuations during the next 10 to 20 years. It will therefore be necessary to rely heavily on model predictions of changes in temperature, rainfall, ice cover, etc. Indeed, in the absence of any direct evidence, concern over the greenhouse effect is based almost entirely on model predictions which, unfortunately, vary so widely that they do not yet provide a sufficiently firm basis for government action.

Climate models, ranging from simple one-dimensional energy-balance models to enormously complex, three-dimensional global models requiring vast computer power, have been developed during the last 20 years, the most advanced at three centres in the USA and the UK Meteorological Office.

Until recently, effort was concentrated on developing models (that evolved from weather prediction models) of the global atmosphere coupled to the oceans and cryosphere (sea and land ice) only through prescribing and updating surface parameters, such as temperature and albedo, from observations. However, realistic predictions of long-term changes in climate, natural or man-made, must involve the atmosphere, oceans, cryosphere and, eventually, the biosphere, treated as a single, strongly coupled and interactive system. The oceans play a major stabilising role in global climate because of their inertia and heat storage capacity. Moreover, they transport nearly as much heat between the equator and the poles as does the atmosphere. The oceans will delay warming of the greenhouse gases because they absorb about half of the CO<sub>2</sub> emitted by burning fossil fuel, and also absorb and transport a good deal of the associated additional heat flux from the atmosphere.

The Meteorological Office has developed perhaps the most advanced model of the global atmosphere coupled to simple models of the ocean, and of land and sea ice, and have used these to study the effects of nearly doubling the present level of CO<sub>2</sub> to 600 ppmv.



**Fig 4: Globally averaged anomalies in surface temperatures for 1900-1987 relative to the average values for 1950-1979 (based on data from the Meteorological Office and the Climate Research Unit, University of East Anglia).**

**The atmospheric model**

The physico-mathematical models of the atmosphere are based on the physical and dynamical laws that govern the birth, growth, decay and movement of the main weather systems that can be resolved by the model. In other words, the models must properly represent the relevant or significant scales of motion and their non-linear reactions, but smooth out all the smaller scale motions that cannot be adequately observed or represented individually — while allowing for their overall contribution to transport and energy conversion processes by representing their statistically averaged properties in terms of larger-scale parameters that can be measured. The parameterisation of these sub-grid scale processes is one of the most difficult and uncertain features of weather and climate models, and occupies a good deal of the present research effort.

The models incorporate the principles of conservation of mass, momentum, energy and water in all its phases, the Newtonian (Navier-Stokes) equations of motion applied to a parcel of air, the laws of thermodynamics and radiative transfer, and the equation of state of humid air. Parameters specified in advance include the size, rotation, geography and topography of the Earth, the incoming solar radiation and its diurnal and seasonal variations, the radiative and heat conductive properties of the land surface according to the nature of the soil, soil moisture, vegetation and snow or ice cover, all of which are computed every five days.

The atmosphere is divided into 11 concentric shells (11 levels) between the surface and 20 mb (~30 km) with three levels in the surface boundary layer (lowest km) to allow calculation of the surface fluxes of heat, moisture and momentum. There are also three levels in the soil to calculate the heat flux through the soil and hence the land surface temperature. The variables are calculated on a spherical grid with mesh 2½° lat. × 3¾° long. with some 30000 points at each level, or about 350000 points in all.

The main physical processes represented in the model are:

*transfer of heat by:*

- solar and terrestrial (infrared) radiation, including absorption by the greenhouse gases' water vapour, CO<sub>2</sub>, ozone and methane, scattering and absorption by clouds, reflection/absorption at the Earth's surface by soil, vegetation, snow, land and sea ice and by the oceans
- shallow and deep convection
- conduction at the Earth's surface.

*the hydrological cycle:*

- evaporation of moisture from land and water surfaces, condensation in the atmosphere to form clouds, rain and snow (precipitation), calculation of run-off and soil moisture
- transport of heat, moisture and momentum in the lowest atmospheric layers (atmospheric boundary layer) by small-scale turbulent motions
- the frictional drag on the atmosphere exerted by mountains, the land surface, breaking gravity waves in the atmosphere, and by waves on the ocean surface.

Starting from initial values derived from observations on a particular day, the governing finite-difference equations are integrated in time-steps of 20 min to give new values of the following parameters at all the relevant grid points, which are then averaged to give monthly mean values over total integration times of years or decades. The most important computed variables are:

- E-W and N-S components of the wind
- Vertical motion
- Air temperature and humidity
- Heights of the 11 specified pressure surfaces
- Short- and long-wave radiation fluxes
- Cloud amount, height and liquid-water content
- Precipitation — rain/snow
- Atmospheric pressure at Earth's surface
- Land surface temperature
- Soil moisture content



Snow cover and depth  
Sea-ice cover and depth  
Ice-surface temperature  
Sea-surface temperature

The atmospheric model is coupled to a simple shallow well-mixed ocean layer only 50 m deep, which transports heat horizontally and vertically and allows computations of the fluxes of heat, moisture and momentum between the ocean surface and the atmosphere. An energy-balance sea-ice model allows the areal cover, snow depth and ice thickness to be calculated every five days and the albedo to decrease gradually as the ice melts and recedes. The surface temperature of the sea-ice is calculated from the heat balance equation at every model time-step.

A 24-hour integration for the whole system involves about  $10^{12}$  numerical operations, so that a complete annual cycle takes about 10 hours on the most powerful supercomputer, the Cray YMP.

Such models have been remarkably successful in simulating the main features of the present global climate — the distribution of temperature, rainfall, winds, etc — and their seasonal and regional variations. They do, however, contain some systematic errors (different in different models) and will require continued development and improvement in order to provide accurate simulations/predictions of the fractionally small but, nevertheless, potentially very important changes that may result from natural or man-made perturbations.

### The doubling of CO<sub>2</sub>

The changes in global temperatures and precipitation to be expected from a near doubling of CO<sub>2</sub> to 600 ppm, as predicted by the Meteorological Office model before the recent changes in the treatment of clouds described below, are shown in Figs 5-7. These changes, achieved when the climate system represented by the model has come into equilibrium with the enhanced atmospheric CO<sub>2</sub>, are the highest predicted by any of the advanced models. A detailed account is given by Wilson and Mitchell (1987). Although recent modifications to the cloud parameterisation scheme have produced smaller changes,

these 'upper' estimates are presented here because they bring out more clearly the geographical and seasonal patterns of the changes which are not greatly altered in the newer simulations.

The global average temperature is increased by 5.2°K, accompanied by a 15% increase in both global precipitation and evaporation of water from the surface. Comparable results from other advanced models are shown in Table 2. The enhanced radiative heating of the surface due to increases in CO<sub>2</sub> and water vapour causes increased evaporation (which restricts the temperature rise), and produces a more intense globally averaged hydrological cycle. Enhanced CO<sub>2</sub> causes increased emission of long-wave radiation from the top of the atmosphere to space and, consequently, a cooling of the stratosphere (Fig 5).

The zonally averaged (along latitude bands) warming is generally most pronounced in high latitudes near the surface in winter because of several amplifying factors. First, greenhouse warming reduces the highly reflecting snow and ice cover and leads to greater absorption of heat, which accelerates the retreat of the ice. Second, in high latitudes in winter, there is a shallow layer of cold, dense air near the surface (an inversion) which traps the increased radiative heating, whereas in the tropics and sub-tropics this is mixed through the whole depth of the atmosphere by deep convection, to produce a smaller warming. Third, the warmer, moister atmosphere transports more latent energy upwards and polewards from the tropics, releasing additional latent heat by condensation in the middle and upper troposphere on the way. These positive feedback effects together result in winter polar surface temperatures being increased by 12°K, compared with only 4°K in the tropics.

The simulated changes in temperature also vary considerably with longitude and season. Greenhouse warming is greatest over sea ice in winter, smallest over sea ice in summer. In summer, sea ice in the Arctic is maintained at constant temperature by melting. Greenhouse warming either produces more melting with no change of temperature, or melts sea ice completely to expose an oceanic mixed layer which warms only slowly because of its large

thermal inertia. The additional heat stored in the mixed layer is released in autumn and winter, delaying the onset of freezing and leading to thinner sea ice through which heat from the ocean can diffuse more rapidly and enhance surface warming in winter. There is also considerable variation in the predicted greenhouse warming within individual continents. In regions where the soil becomes drier, evaporation may be restricted leading to increased warming, and vice versa.

The increase in atmospheric moisture accompanying the warming due to enhanced CO<sub>2</sub> would lead one to expect increased precipitation, especially in regions where the low-level winds converge to produce rising motions, notably in the extratropical depression belts and along the intertropical convergence zone. This is confirmed in Fig 7, which also shows an increase in the summer monsoonal rains over Southeast Asia. There is also a general increase in precipitation in high latitudes, especially in winter, consistent with increased transport of moisture from low latitudes. Fig 7 also shows large areas of slightly *decreased* rainfall, especially in the sub-tropics in DJF and over Euro Asia in the northern summer. These large-scale latitudinal and seasonal changes are broadly reproduced in the various models, but they show considerable differences in their predictions on regional and small scales. Models of higher resolution and improved physics will be required to resolve these differences. This is important because global or zonal averages are of little use in assessing the effects of greenhouse warming on agriculture, forestry, energy consumption, water supply, etc.

### Sensitivity of models

It is important to note that the model results are quite sensitive to the representation of the many interacting physical processes, in particular, the simulation of clouds and their influence on the incoming solar and outgoing terrestrial radiation, to the fluxes of heat and moisture between the oceans and the atmosphere, to the positive feedback between changes in ice cover and ocean or atmosphere temperature, and changes between melting snow cover and soil moisture.

This sensitivity of the model simulations, and the differences or deficiencies of the various models in treating these physical processes, are largely responsible for the rather wide range of predicted changes of climatic parameters due to prescribed increases of CO<sub>2</sub> shown in Table 2.

Climate models are particularly sensitive to the parameterisation of clouds, which may affect the computed equilibrium greenhouse warming by a factor of more than two. Important factors are the coverage, height and type of cloud; their optical thickness, their reflectivity, absorptivity and emissivity, which are determined by the concentration and size of the droplets and ice particles. Depending on these factors, clouds can generate a feedback effect that is either positive or negative. Thus a relative increase in high cloud, which has a relatively low albedo and emits less radiation, tends to warm the atmosphere, whereas a relative increase in low cloud with its higher

**Table 2: Global mean changes caused by doubling CO<sub>2</sub> as predicted by various models under equilibrium conditions with different cloud schemes**

All models consist of a global atmosphere with 9 to 11 levels and a shallow mixed-layer ocean with prescribed heat transport				
Model	Cloud representation	Radiative properties of clouds	Temperature rise °K	Precipitation increase %
UKMO (1)	Empirical — linked to relative humidity All-water clouds	Fixed	5.2	15
UKMO (2)	Computed liquid water and ice content	Fixed	3.2	8
UKMO (3)	" "	Variable — function of water and ice content	1.9	3
GFDL	Empirical — linked to relative humidity	Fixed	4.0	8
GISS	" "	Fixed	4.8	13
CCC	" "	Variable	3.5	4

UKMO: UK Met Office      GFDL: Geophysical Fluid Dynamics Laboratory, Princeton  
GISS: Goddard Institute of Space Studies      CC: Canadian Climate Centre, Toronto

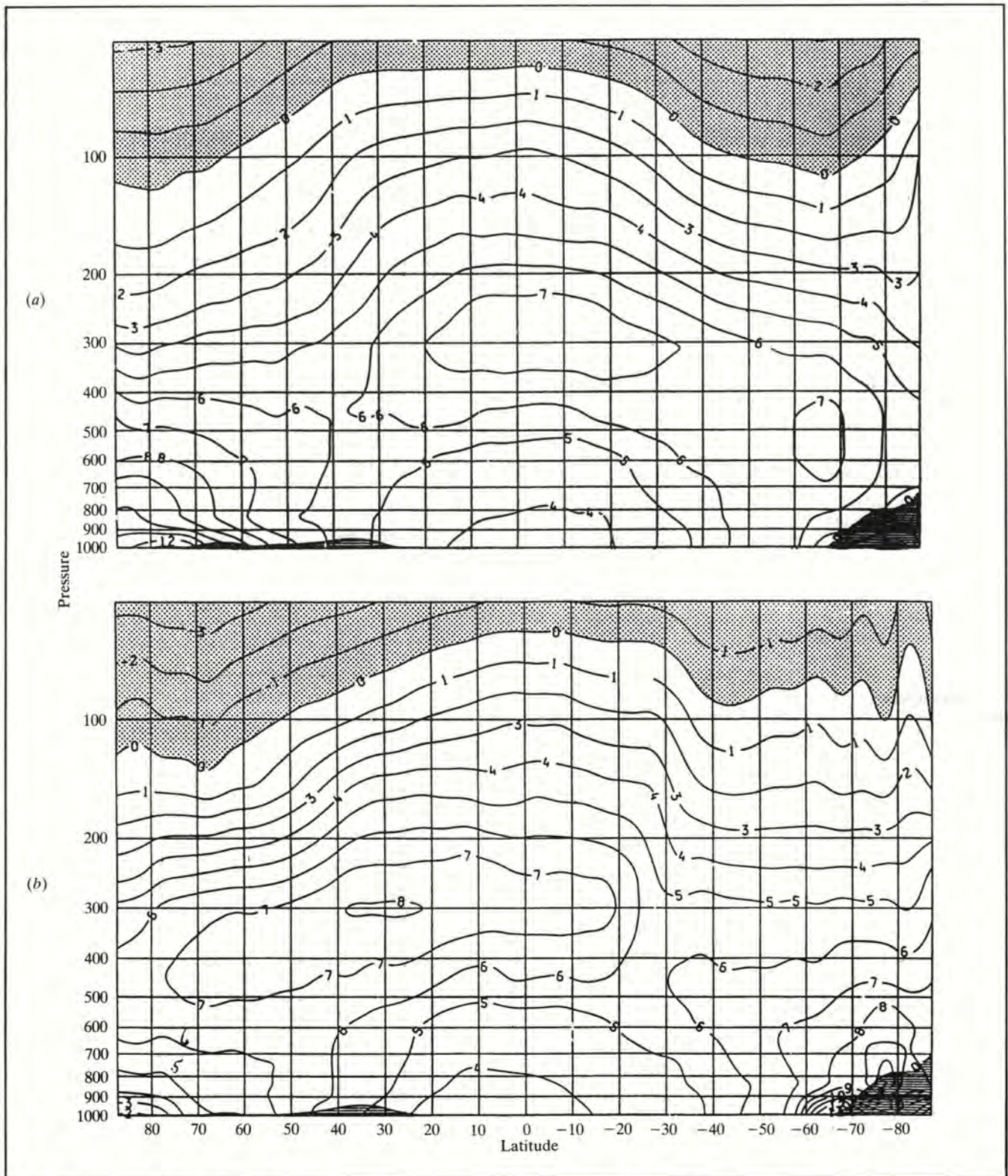


Fig 5: (a) Changes in the zonally-averaged air temperatures (K) as functions of height and latitude, produced by doubling CO<sub>2</sub> concentrations from 320 to 640 ppm in the Meteorological Office model (Wilson & Mitchell, 1987), for the months of December, January and February combined. Areas of cooling are shaded. (b) As for (a) but for June, July and August (diagrams provided by Dr J Mitchell, Meteorological Office).



albedo and larger emission of radiation to space, will have a cooling effect. Overall, clouds have a net cooling effect on the planet of about  $15 \text{ W/m}^2$  so that, on a simplistic view, doubling of  $\text{CO}_2$  could be completely offset by a 20% increase in the present cloud distribution, but by a smaller percentage increase if this were mainly low cloud.

The recent introduction of a more realistic representation of clouds and their radiative properties in the Meteorological Office model has led to a marked reduction in the predicted warming due to enhanced  $\text{CO}_2$ . For the model simulations described in the previous section, the cloud cover was calculated from an empirical formula on the basis of the prevailing relative humidity, but the liquid-water content of the cloud and its detailed radiative properties were not computed.

The new version of the model calculates the liquid water content of the cloud as the difference between that formed by condensation in air cooled by vertical ascent and that released as precipitation. Also, ice crystals are introduced above the  $-15^\circ\text{C}$  level in concentrations which increase with decreasing temperature. Furthermore, the different radiative properties of the water droplets and ice crystals are taken into account. These changes result in an atmosphere with doubled  $\text{CO}_2$  producing an increase in low- and medium-level cloud cover at middle latitudes, and a reduction in the global average greenhouse warming from  $5.2\text{K}$  to only  $1.9\text{K}$  (Mitchell *et al* 1989). The end result is to change the Meteorological Office predictions from being the highest to the lowest of those shown in Table 2.

Other important feedback effects result from the melting and retreat of the ice and snow cover induced by greenhouse warming. As the highly reflecting sea ice retreats and is replaced by more strongly absorbing sea water, the latter is warmed, causes further melting of ice, and so enhances the greenhouse warming. The greenhouse warming also accelerates the melting and retreat of the snow cover at middle and high latitudes in spring. The newly exposed soil is then subject to greater warming and evaporation and the soil moisture is reduced.

The model simulations suggest that the combined effect of these various feedback mechanisms is to enhance the magnitude of the warming that would arise from the purely radiative effects of the greenhouse gases, including water vapour, by a factor of between 1.5 and 3.5, depending on the particular model used, and imply values for the global average warming for nearly doubling  $\text{CO}_2$  to 600 ppmv of between  $2^\circ\text{K}$  and  $5^\circ\text{K}$ . By the time  $\text{CO}_2$  reaches this concentration, the other greenhouse gases will have increased these figures by at least 50%, even if the Montreal Agreement is carried out.

Irrespective of the actual magnitudes of the climate changes predicted by the various models, it is important to realise that they involve only very small percentage changes in the normal radiative fluxes — much smaller than the errors in either measurements or calculations of these fluxes. We therefore have to rely on the assumption that systematic errors

will be the same in the 'perturbed' and normal (control) models, and so disappear in the differences which may be attributed to the greenhouse effect.

Furthermore, these greenhouse 'signals' are comparable in magnitude with the interannual variations that occur both in the models and the real atmosphere, so it is necessary to assess whether they are significantly relative to the natural noise. Such statistical tests are made as a routine in the Meteorological Office model, the results described in this section and shown in Figs 5-7 being significant at the 90% confidence level.

#### Future model development

We have already intimated that current models contain some important deficiencies leading to uncertainty in the prediction of greenhouse effects which should therefore be taken only as broad indications of likely changes, giving little weight at this stage to the actual magnitudes, and even less to their significance on regional and smaller scales. The hope is that continued development of the different models will cause their predictions to converge, narrow the range of uncertainty, and thereby provide more reliable guidance for remedial action.

Improvements are likely to come mainly from better representation of the physical processes and greater spatial resolution. The former will require more intensive study of the processes in the real atmosphere using highly-instrumented research aircraft, radars, lasers, etc. Higher resolution, doubling of which increases the amount of computation at least eightfold, requires greater computing power than is currently available. One therefore has to choose, or effect a compromise, between the need for high resolution and more detailed physics leading to greater accuracy on the one hand, and the need for long model runs to study interannual and longer-term variations in climate on the other.

These longer-term changes, on timescales of decades to centuries, will be largely determined by the oceans, not only in the surface layers, but at depth. It is therefore necessary to develop fully three-dimensional models of the global ocean circulation which are coupled to, and driven by, the winds of the atmospheric model. Such models are being developed in the USA and the Meteorological Office with encouraging success and should be ready to utilise data on sea-surface temperature, surface winds and wind stress, and circulations in the surface layers of the ocean, from the new oceanographic satellites in the early 1990s and beyond. However, as yet very few long-term integrations have been made with these fully coupled models, which will require even more computing power, especially if it proves necessary to resolve the ocean 'weather' systems such as gyres, eddies and fronts that are an order of magnitude smaller in linear dimension than their atmospheric counterparts.

The improvement of climate models will also depend on an adequate supply of observations from all parts of the climatic system, not least the atmosphere. These are required for input to, and initialisation of, the models

for their validation, and for the detection and monitoring of climate changes in the climate itself. Provision of these observations is one of the main functions of the World Climate Research Programme and the World Ocean Circulation Experiment, which were described by Mason (1987).

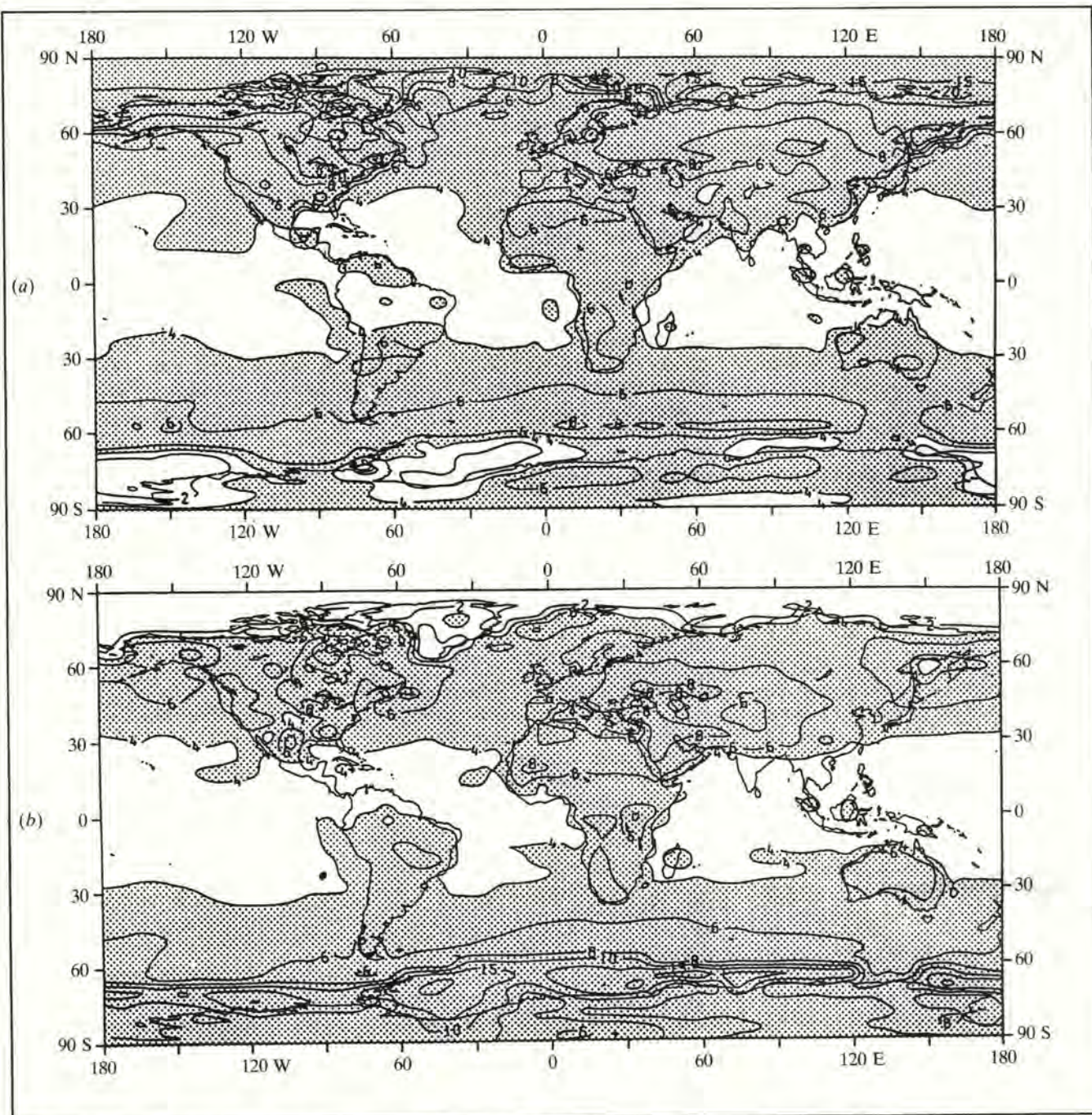
#### Time-dependent simulations

Virtually all the model calculations on greenhouse warming to date have assumed that both the normal climate system (control model) and the system perturbed by enhanced levels of greenhouse gases are in equilibrium at all stages. The  $\text{CO}_2$  is doubled in one step and the model climate system is allowed to come into equilibrium with the new concentration. In the real world this will never be the case because the trace gases are increasing gradually with time and the response of the total climate system depends upon a variety of physical and biogeochemical processes acting on widely different timescales. The atmosphere, together with the sea ice, the upper layers of the ocean and the land-surface hydrology, respond quite rapidly and reach a quasi-equilibrium in the model after a few annual cycles. On the other hand, the deep ocean circulation and the land-based ice sheets respond much more slowly on time scales of hundreds of years, and so will constantly lag behind the response of the atmosphere.

The large thermal capacity of the oceans and their ability to store and transport some of the additional heat flux from the trace gases will delay the greenhouse warming but also ensure that temperatures will continue to rise long after any reduction in emissions takes place. This is probably the main reason why there is, as yet, not convincing observational evidence of temperature rises due to the gases accumulated so far.

The delaying effect of the oceans will be determined by the net additional heat flux at the ocean surface produced by the greenhouse gases and the effective heat capacity of the ocean which is determined by the penetration of the heat below the surface. Initially the warming will involve only the well mixed, stably stratified, 'warm water shell' down to a mean depth of 100 m or so and, even after 20 years, may involve only the top 500 m, as indicated by the observed penetration of tritium ejected into the atmosphere during the 1950s series of thermonuclear explosions.

The actual changes in climatic parameters for a given increase in greenhouse gas concentrations are therefore likely to be smaller than those predicted by the 'equilibrium' models, and to be delayed. More realistic estimates of the magnitude and timing of the greenhouse effects will require the concentrations of the gases to increase gradually at current or predicted rates in a model which couples the atmosphere to a global deep ocean. Only a very few model simulations of this type have been published. The results of one experiment by Manabe (1990) in which the  $\text{CO}_2$  was increased at 1% per annum compound to double in 70 years, are in Fig 8 shown plotting the increase in surface air temperatures over the globe, averaged over one annual cycle. The globally averaged value of  $2.3^\circ\text{K}$  is much lower



**Fig 6: (a) Changes in air temperature near the surface as the result of doubling CO<sub>2</sub> concentrations for December, January and February combined. Areas where the warming exceeds 4K are shaded. (b) As for (a) but for June, July and August (diagrams provided by Dr J Mitchell, Meteorological Office).**

than that obtained by all other advanced models, except the latest Meteorological Office version mentioned above. The reduced warming is especially marked in the Southern Hemisphere, which shows little enhanced warming in the Antarctic compared with that in the Arctic. This is explained by the vertical ocean circulation in the southern oceans, which produces a deep down-welling of water around 65°S that carries much of the additional greenhouse flux of heat from the surface to great depths (see Fig 9) where it is stored for many decades. This very interesting result should be treated with caution because this is only the first experiment with a model that, like all coupled ocean-atmosphere models, has considerable difficulty in reproducing the correct fluxes of heat and

moisture at the interface. However, it points to the moderating and delaying effect of the oceans on greenhouse warming of the atmosphere. According to this simulation, a temperature rise of 0.5°K would occur after 20 years.

Just when, during the next century, the greenhouse gases will reach concentrations at which they will produce significant climate changes, will depend also on the rates of exchange of the gases between the atmosphere and the oceans, the fraction retained in the atmosphere, the take-up, storage and release of CO<sub>2</sub> by phytoplankton, forests and other vegetation, all involving biological processes that will have to be incorporated into global climate models at a suitable stage. The first requirement is to obtain high-quality

observational data, which is one of the objectives of the International Geosphere Biosphere Programme. The National Biogeochemical Ocean Fluxes Study, which is part of the international Joint Global Ocean Fluxes Study, and which will form a strong interface with the World Climate Research Programme, is an important first step along this road. However, by far the most important factor in determining the future levels of atmospheric CO<sub>2</sub> and other greenhouse gases, and hence the timing of significant climate changes, will be the future rates of emissions, scenarios for which differ so widely that estimates of the time likely to elapse before the CO<sub>2</sub> reaches double the present-day concentration range from 80 to 130 years.

Predicted rises in average global temperature

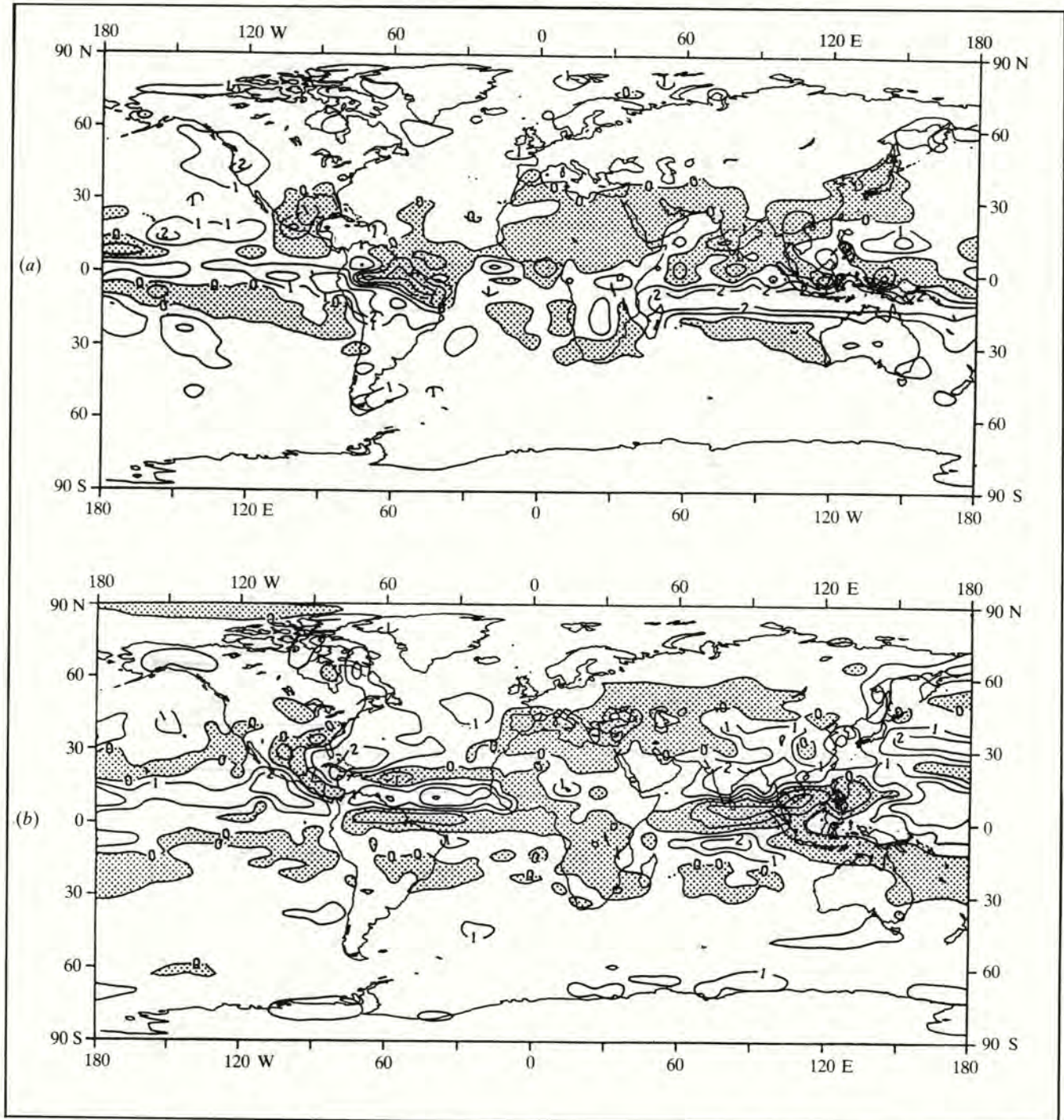
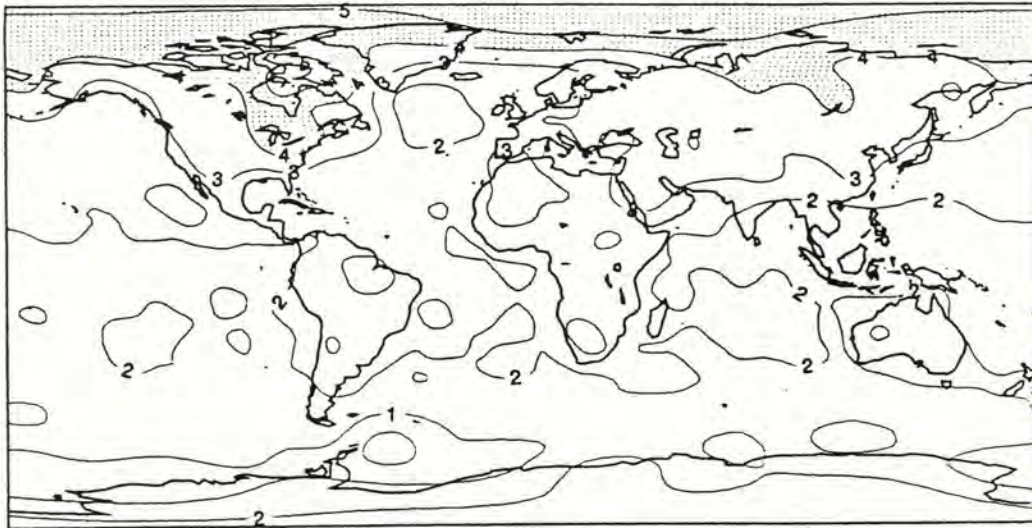


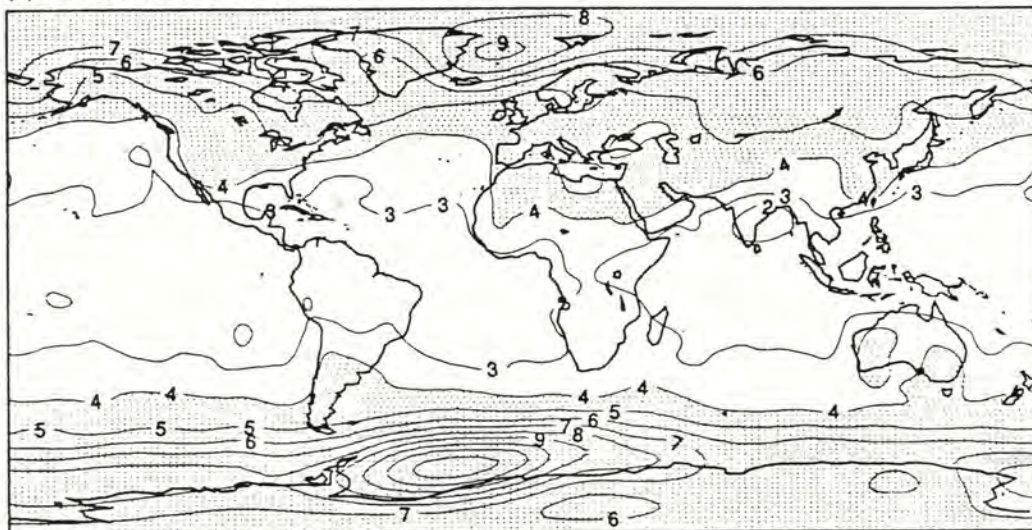
Fig 7: (a) Changes in precipitation at the surface (in mm day<sup>-1</sup>) as the result of doubling CO<sub>2</sub> concentrations for December, January and February combined. Areas of precipitation decrease are shaded. (b) As for (a) but for June, July and August (diagrams provided by Dr J Mitchell, Meteorological Office).



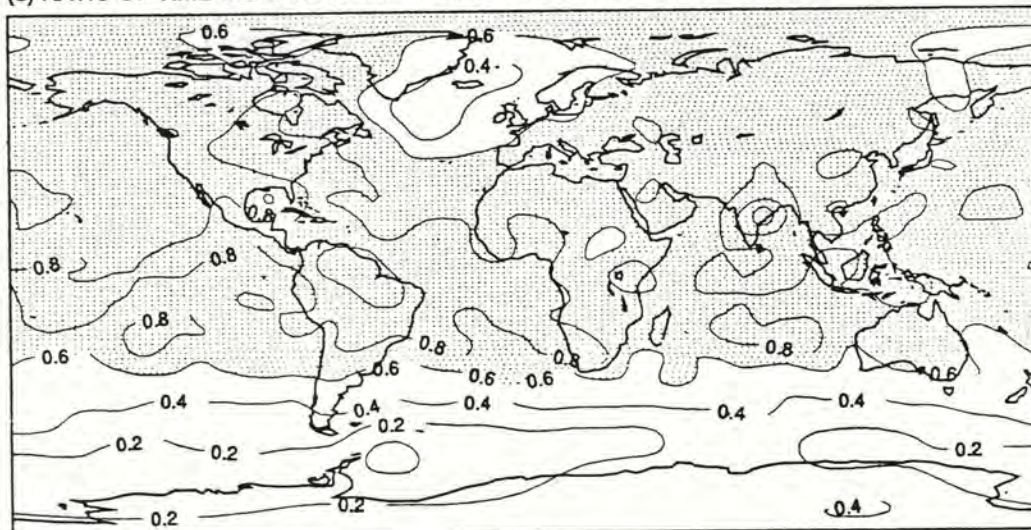
(a) YEARS 60-80 OF TIME-DEPENDENT TEMPERATURE RESPONSE



(b) EQUILIBRIUM TEMPERATURE RESPONSE



(c) RATIO OF TIME-DEPENDENT RESPONSE TO EQUILIBRIUM RESPONSE



*Fig 8: (a) The geographical distribution of the time-dependent response of surface air temperature ( $^{\circ}\text{C}$ ) in the coupled ocean-atmosphere model to a 1%/year increase of atmospheric  $\text{CO}_2$ . The result represents the difference between the 1%/year perturbation run and the control run for the 60th-80th year period when the atmospheric  $\text{CO}_2$  concentration approximately doubles. (b) The geographical distribution of the equilibrium response of surface air temperature ( $^{\circ}\text{C}$ ) in the atmosphere-mixed layer ocean model to a doubling of atmospheric  $\text{CO}_2$ . (c) The geographical distribution of the ratio of time-dependent to equilibrium responses shown above.*



for a number of emission scenarios published in the IPCC Report (1990) are shown in Table 3. These are computed from a simplified atmosphere-ocean model calibrated against the GDFL global circulation model described above, to give a 2.5°K rise when in equilibrium with a doubled CO<sub>2</sub> concentration.

## Sea-level rise

A potentially important consequence of greenhouse warming is the melting of sea ice and ice sheets on land, with only the latter resulting in a rise in sea level. The sea level will also rise as the ocean waters expand in response to the additional warming. Estimates of these consequences involve large uncertainties because of lack of observations and of understanding of the mass balance and dynamics of glaciers and ice sheets. Moreover, there is considerable uncertainty in the predicted increases in surface temperature due to greenhouse warming.

Glaciers and small ice caps are very small in volume compared with the major ice sheets, but are liable to melt much more rapidly. Their melting is calculated to have contributed about 40% to the total sea-level rise of some 10 cm over the last hundred years (see Table 4).

The mass balance of the great Antarctic ice sheet, and of the Greenland ice sheet with only one-tenth the volume, are determined by the difference between accumulated snowfall on the one hand, and melting and calving on the other. In Antarctica, observations suggest that accumulation is very nearly balanced by calving of slabs of ice on the ice shelves with little melting taking place because of the very low air temperature. In Greenland, accumulation is balanced about equally by melting and calving. In neither case is there any direct evidence that the ice sheets are far from equilibrium, so that together they are unlikely to have contributed more than 20% to sea-level rise over the last century.

The remaining 40% of this rise is attributed to thermal expansion of sea water. Since this is

**Table 3: Future predictions of CO<sub>2</sub> concentrations, rises in global temperature and sea level for various emission scenarios**

<b>(A) Business-as-usual, high emission scenario</b>					
CO <sub>2</sub> emissions continue to increase linearly with time adding 2% of 1990 value each year. Montreal Agreement 75% implemented CH <sub>4</sub> and N <sub>2</sub> O continue to increase at 1990 rates					
	1990	2030	2060	2100	AD
CO <sub>2</sub> concentration	354	470	590	850	
ΔT (°K)	0	1.1	2.0	3.25	
Sea-level rise (cm)	0	18	38	65	
<b>(B) All emissions kept constant at 1990 rates</b>					
CO <sub>2</sub> concentration	354	420	465	520	
ΔT (°K)	0	0.72	1.1	1.6	
Sea-level rise	0	15	27	42	
<b>(C) 2% pa (compound) reduction in all emissions from 1990</b>					
CO <sub>2</sub> concentration	354	388	395	390	
ΔT (°K)	0	0.4	0.4	0.3	
Sea-level rise	0	11	18	21	
<b>(D) 2% pa increase in all gas emissions 1990-2010, thereafter a 2% pa decrease</b>					
CO <sub>2</sub> concentration	354	436	458	464	
ΔT (°K)	0	0.93	1.10	1.0	
Sea-level rise	0	17	28	34	

very sensitive to temperature, being six times greater at 25°C than at 0°C, the rise in sea level depends very much on the depth to which the warming penetrates and therefore the mass of water which expands. This can, in principle, be determined from a fully coupled atmosphere-ocean model, but no such long-period calculations have yet been made. Calculations based on a simple one-dimensional model and quoted in the IPCC Report (1990), indicate that thermal expansion has contributed 2-6 cm, with a best estimate of 4 cm, to a total estimated rise of 10.5 cm (Table 4).

If atmospheric and surface temperatures increase due to greenhouse warming, thermal expansion of the oceans and melting glaciers are likely to continue to make the largest contributions to sea-level rise (as shown in Table 5), where the best estimates of contributions for a temperature rise of 1.1°K by 2030 are 10 and 7 cm, respectively, to a total rise

of 18 cm. If by 2060 the global warming increases to 2.0°K, the corresponding sea-level rise is estimated to be 38 cm; by 2100 it may rise by 65 cm in response to a temperature increase of 3.25°K. Estimates for lower emission scenarios leading to slower temperature increases are given in Table 3.

All these estimates of sea-level rise, which are probably uncertain by a factor of two, are much less than exaggerated claims based on the assumption that the western Antarctic ice sheet will largely disintegrate and melt. Most glaciologists discount such a scenario, rendered even more unlikely by the recent model climate simulations described above, which produce very little greenhouse warming in Antarctica.

## Conclusion

It is virtually certain that the troposphere is warming very slowly in response to the continually increasing concentration of CO<sub>2</sub> and other 'greenhouse' gases, but the signal is as yet too small to detect above the large natural climate variations, partly because it is being delayed by the thermal inertia of the oceans. Predictions of the magnitude and timing of the greenhouse warming and of the concomitant changes in rainfall and other climate parameters, come entirely from physico-mathematical models of the global climate system. Unfortunately, the differences between the various model predictions, which are very sensitive to how clouds and their interaction with the radiation fields are represented, are too large to provide firm guidance for major policy decisions. Continued improvement in model resolution and model physics should cause the predictions to converge and thereby narrow the range of uncertainty. This will require several years of model development, especially in respect of the oceans; much faster computers; and, above all, an adequate supply of global observations from both the atmosphere and the oceans to feed and validate the models, and to monitor the actual changes in climate that may eventually become evident.

In the meantime, although the current best

**Table 4: Estimated contributions to sea-level rise over last 100 years (in cm)**

	Low	Best estimate	High
Thermal expansion	2	4	6
Mountain glaciers	1.5	4	7
Greenland Ice Sheet	1	2.5	4
Antarctic Ice Sheet	-5	0	5
Total	-0.5	10.5	22
Observed	10	15	20

From IPCC Report, p 274

**Table 5: Estimates of contributions to sea-level rise (in cm) from 1990-2030 according to business-as-usual scenario in Table 3**

	Low	Best estimate	High
Thermal expansion	6.8	10.1	14.9
Mountain glaciers	2.3	7.0	10.3
Greenland	0.5	1.8	3.7
Antarctica	-0.8	-0.6	0
Total	8.8	18.3	28.9

From IPCC Report, p 276



estimates of global warming are not so alarming as to warrant *major strategic* changes in energy, agriculture, etc, industrialised countries should take all reasonable and practicable steps to restrain or reduce energy consumption, utilise all fuels more efficiently, and explore economically promising alternatives to fossil fuels. The decision of the government to restrict UK emissions of CO<sub>2</sub> by 2005 to current levels and to reduce emissions of CFCs in line with the Montreal Agreement are realistic first steps.

In addition, we should develop, without delay, adaptive strategies in agriculture, forestry, coastal defences, water supply, and so on, to make the economy less vulnerable to climatic changes when they occur. It would appear that we have a breathing space of some 50 years but this may prove too optimistic; in any case, it is none too long.

**Acknowledgement**

This written version of the lecture is largely based on an article entitled *The Greenhouse Effect*, published in *Contemporary Physics* in November 1989 and now extended and brought up to date.

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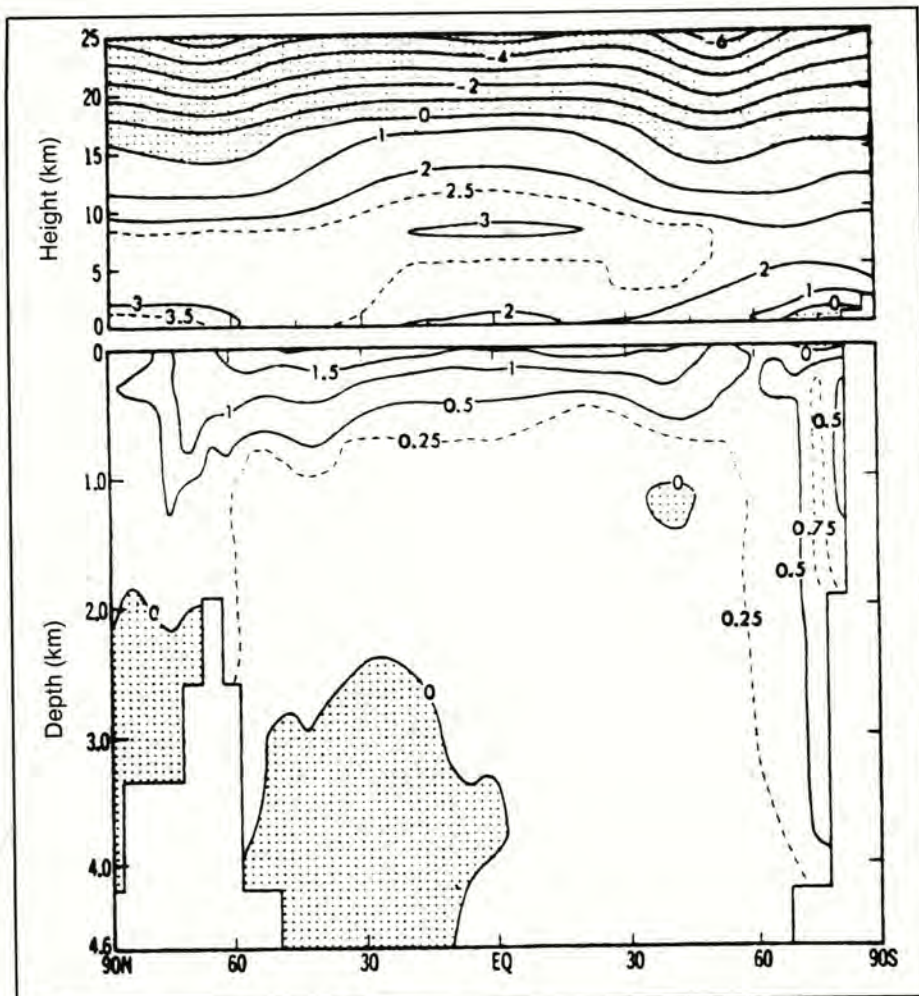


Fig 9: Zonal-mean difference in temperature (°C) of the ocean-atmosphere model between two integrations. The difference represents the decadal average over years 61 – 70. The atmospheric data have been interpolated to isobaric surfaces.

The Institute of Energy

***BENEFITS OF MEMBERSHIP***

Various benefits of membership were advertised in the **January 1991** issue of *Energy World*. One such benefit referred to discounts available to members on car hire from Hertz. The Institute has now received a supply of Hertz Business Partners Club cards and any member wishing to obtain a card should write to: The Membership Office (Ref MB), The Institute of Energy, 18 Devonshire Street, London W1N 2AU (Tel: 01-580 0077).



1.2% sulphur where the emission has to be below 230 mg/MJ, ie approximately 75% removal. Three processes — the wet limestone/gypsum, semi-dry and Tampella's LIFAC — were compared. In the latter process, SO<sub>2</sub> is removed initially by injection of limestone in the furnace with further removal in a reactor upstream of ESP where the uncombined calcium oxide is activated with water. The cost analysis showed that LIFAC was economical for sulphur level not exceeding 1.2%.

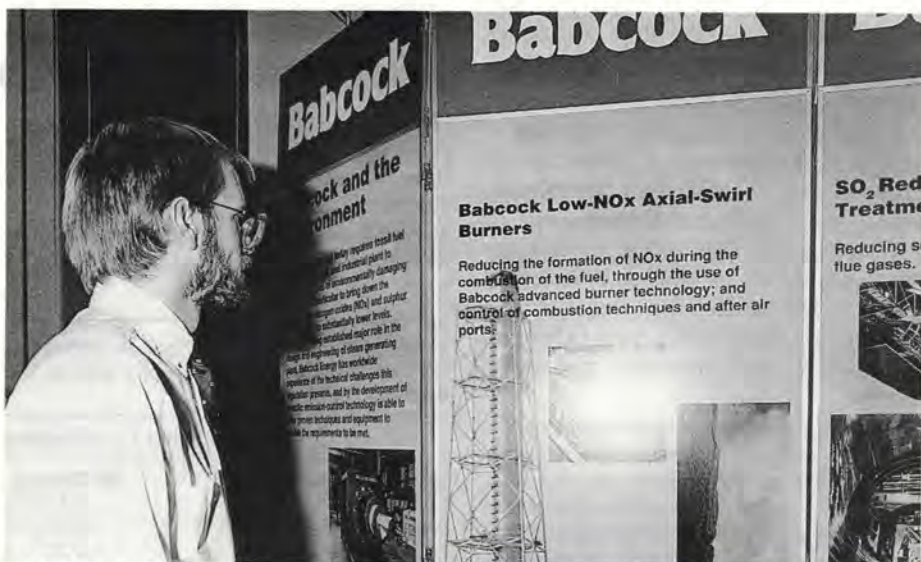
Borchert Kassebohm of Stadtwerke, Düsseldorf AG described the cost of the Stadtwerke semi-dry scrubbing system based on a modular design of an absorber using lime spray through nozzles. Based on a 150 MWe utility plant firing coal with 1.3% sulphur, and achieving 85% removal for 5,000 operating hours per year, total cost works out at approximately 0.3p/kWh.

Wang Jensen of Volund Energisystemer of Denmark and Benny Ekman of Norrkopings Kraft AB, Sweden gave the last talk of the seminar on their FGD system based on injection of dolomite or limestone into the furnace of stoker-fired plants. Based on 45-50% removal efficiency with the prospect of improvement, it is a simple process where the stringent Swedish emission limit of 200 mg/MJ is being met for coal of varying sulphur levels up to 1.4%.

It was evident from the various speakers that the choice of a particular FGD system will be dependent on multiple factors and each unit has to be assessed on its own merit. If the popularity of a seminar can be judged by the discussions that followed, the seminar was a success, and the objective of the Institute to initiate an awareness of the costs involved in meeting the EEC legislation, was hopefully fulfilled. □



Pictured above from left to right, top row are Doug Willis (President of the Institute), Michael Tunnicliffe, Wang Jensen, Benny Ekman; bottom row, Judith Higgins (Conference Manager at the Institute), Borchert Kassebohm, Erkki Valimaki, Dr Anupam Sanyal (Conference Chairman) and Ted Pugh (past President of the Institute).



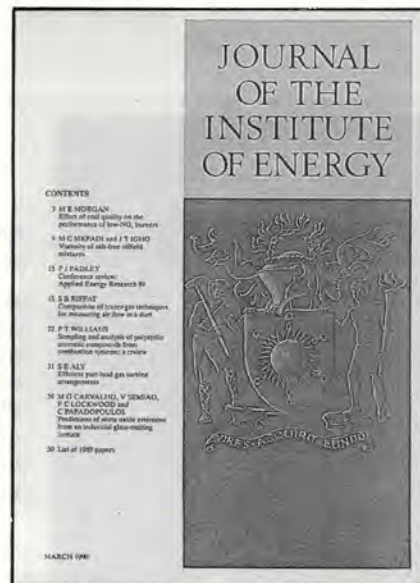
A delegate takes a break from the conference proceedings to look around the accompanying exhibition.

## Are you missing out on the Journal?

The *Journal of the Institute of Energy* is the technical journal of record for the Institute. Published quarterly, it carries refereed technical papers on a wide range of subjects and it is available to members of the Institute who register their wish to receive it. To put yourself on the mailing list, simply write to the Membership Secretary at The Institute of Energy, 18 Devonshire Street, London W1N 2AU, stating your preference to receive the Journal (please include your membership number in all correspondence).

To those outside of membership, it is available on subscription jointly with *Energy World* — price £140 (UK and overseas).

Examples of papers recently published include: *The burning velocities of methane and SNG mixtures with air* (MS Haniff, A Melvin, DB Smith and A Williams); *Optimisation of the design and operation of coal flames in cement kilns* (TM Lowes and LP Evans); and *Pulverised-coal-fired dilute-phase hybrid boilers: a new concept* (P Basu, EAM Gbordzoe and A Sett).





# Options for limiting CO<sub>2</sub> from power generation

THE INTERGOVERNMENTAL Panel on Climate Change<sup>1</sup> has highlighted in its report both the predictions of global warming and the uncertainties surrounding them. In the light of both prediction and uncertainty it advocated response strategies that are justifiable in their own right, economically efficient, and cost effective, and able to serve multiple social, economic and environmental purposes.

It further invited nations or groups of nations to consider setting targets for the emission of CO<sub>2</sub> and other greenhouse gases. The European Community, in response to this, has agreed to stabilise emissions of CO<sub>2</sub> by 2000 at 1990 levels. It is not clear yet how this target will be met but electricity must expect to bear its share along with transport and other sectors.

This article examines the options open to the electricity sector. The first option is higher efficiency and conservation by the end user. The indications are that vigorous action here could offset growth in electricity demand for a decade or more. The other options examined are supply-side-orientated with savings available over a range of timescales.

## End-use efficiency

Reports by the Building Research Establishment,<sup>2</sup> the Energy Research Unit<sup>3</sup> (ETSU) and the Watt Committee<sup>4</sup> indicate that substantial savings can be achieved through end-use energy efficiency and conservation

by Ken Gregory\*

**That the greenhouse effect exists seem certain. What the experts are unable to agree on are the future consequences of global warming. The Intergovernmental Panel on Climate Change has recommended responses that are justifiable in their own right, just in case the predictions prove to be wrong. In this article Ken Gregory examines the possible responses within the electricity sector, not only in terms of their efficiency in limiting CO<sub>2</sub> emissions, but also with a view to their economic, social and additional environmental effects.**

measures. Some of the savings they describe — for example, better insulation — apply to all forms of energy, while others are specific to electricity. The potential savings related to electricity use in the domestic sector are given in Table 1.

**Table 1: Potential cost effective savings in CO<sub>2</sub> emissions from electricity use in the domestic sector**

Reduction in CO <sub>2</sub> emissions	
Source of Saving	Mt Carbon
Loft insulation	0.11
Wall insulation	0.51
Double glazing	0.31
Draft proofing	0.20
Water tank	0.22
Fridges & freezers	0.91
Television	0.27
Lights	0.65
Other appliances	0.18
<b>Total</b>	<b>3.36</b>

The savings shown represent 17% of current electricity use in the home and if pursued could

offset the growth in consumption for a decade or more; other savings may then come along to offset any further increase in consumption. The savings are described as cost effective — it would *pay* householders to adopt them. However, they are only slowly being adopted for a variety of reasons — inertia, lack of information, moving house, other priorities, and so on, and it would require positive government action to bring about their implementation.

A similar picture applies to the commercial and industrial sectors — savings can be made by companies willing to invest time and money. Overall the indications are that a broad programme of energy efficiency and conservation by end users, if pursued vigorously, could allow emissions of CO<sub>2</sub> from power stations to be kept stable for a decade or more.

## Combined cycle gas turbines

The development of reliable gas turbines operating at high temperatures is allowing a new generation of gas-fired power stations to be built with efficiencies of around 47% (based on the gross calorific value). The new stations, known as combined cycle gas turbine (CCGT), add a steam cycle using the hot exhaust gases to the gas turbine and produce around half the amount of CO<sub>2</sub> per unit of electricity as conventional coal-fired stations. They are expected to take the bulk of the market for new power stations in the UK over the next few years and will significantly limit overall CO<sub>2</sub> emissions from the sector. The extent to which they can continue to penetrate the sector will depend upon the availability of very substantial additional supplies of gas at acceptable prices. CCGT appears to be favoured to play a significant role in other European countries and the competition for the available supplies



## The author

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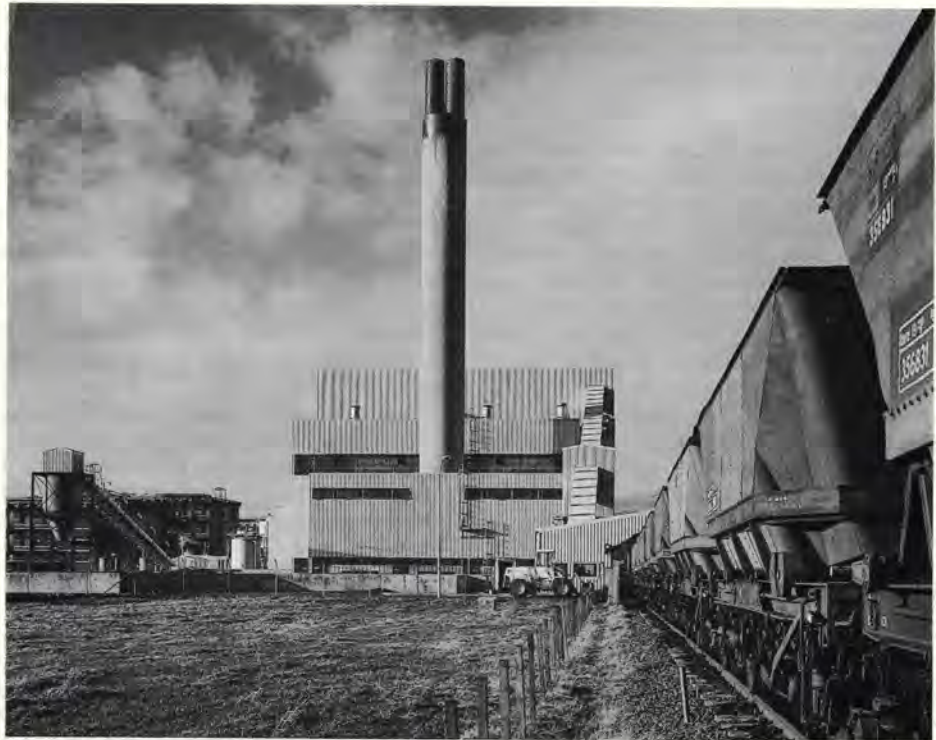
seems likely to lead to much higher gas prices.

One variation on the CCGT theme which is under active consideration by both PowerGen and National Power is to add gas-fired gas turbines to the front ends of existing fossil fuel power stations. The hot exhaust gases would be fed into existing boilers, displacing some of the existing fuel. One attraction of the approach is that once satisfactory design studies have been completed the extra capacity can be added quickly and cheaply. The gas turbines themselves will yield around 30% efficiency, but since the exhaust gases will displace other fuel in the existing boilers, the marginal conversion efficiency of the additional capacity is near 100%. Further, since gas has a lower carbon content than either coal or oil, the additional output can be achieved with the emission of little or no extra CO<sub>2</sub>.

Finally, a small note of caution must be struck. Methane itself is a powerful greenhouse gas and methane leakage to the atmosphere can offset its advantage over traditional coal- or oil-fired power stations. Within Western Europe, leakage rates to new power stations are not expected to be significant, particularly as the use of old low-pressure gas distribution networks will normally be avoided. However, there is concern that leakage from the Siberian production and distribution network may be substantial. Until these problems are solved, policies which directly or indirectly require additional supplies of Siberian gas may increase rather than reduce the emission of greenhouse gases.

## Nuclear power

Nuclear power has been in retreat in most countries for a decade or more. The accidents at Three Mile Island and Chernobyl emphasised the dangers of nuclear power, with Chernobyl in particular responsible for the spread of radioactivity over a wide area. One consequence of these and other concerns has been the greater emphasis that has been placed on safety — and the resultant higher costs. Within the UK, the high costs of nuclear power only became apparent to the government when they tried, and failed, to sell off nuclear power stations as part of the electricity privatisation package. Several additional factors were brought out during the privatisation debate. First, the issues of decommissioning and radioactive waste disposal have not been satisfactorily solved, at least in the eyes of potential investors. Second, the discount rate traditionally used by the old CEBG was 5% — roughly equal to the real return (ie after inflation) that an individual can get from a building society. Industry typically uses a 20% real discount rate for normal risk investments. This had the effect of substantially increasing capital charges and moving the balance against high capital cost projects. In this case, the costs of nuclear electricity became much higher than the costs of electricity from coal or gas. Finally, the alternatives to nuclear power now have much shorter construction times, which mean savings in interest during construction as well as the margin of spare capacity that has to be kept against unexpected growth in electricity demand or problems with power station construction.



Modern CHP stations such as this coal-fired unit at Roche Products, Dalry, Scotland can contribute to reducing emissions of CO<sub>2</sub>.

Can nuclear power overcome these problems and contribute to reducing CO<sub>2</sub> emissions? The government has promised to review the position in 1994. Nuclear power produces only a few per cent of the CO<sub>2</sub> associated with coal- or gas-fired power stations — from construction, uranium mining and fuel processing. The adoption of nuclear power for baseload electricity could reduce UK CO<sub>2</sub> emissions by perhaps 20% (from what they would otherwise have been). The costs would be high — electricity prices would double depending on whose estimates one believes — and would be higher still if such a policy included the premature closure of existing power stations.

## Renewable energy—the NFFO

Renewable energy is largely CO<sub>2</sub>-free — the main contribution in most cases coming from construction. One exception is the combustion of waste in its various forms, which in recent years has come to be regarded as renewable energy. However, as much of the waste would eventually decay to produce carbon dioxide, or to produce methane, which is worse, it is reasonable to define waste combustion as largely CO<sub>2</sub>-free.

Renewable energy, principally in the form of hydroelectricity in Scotland, accounts for around 1.5% of the electricity generated in the UK at present. The Department of Energy have stated an intention to increase this figure and are obliging regional electricity companies to contract for electricity from renewable sources. Such electricity will then be subsidised by a levy, designed initially to provide a subsidy for nuclear power, on fossil-fuel-produced electricity. The levy will add 11% to fossil fuel electricity prices in 1991/2.<sup>5</sup>

The first tranche of this non-fossil fuel obligation (NFFO) was announced in 1990. The regional electricity companies have con-

tracted for 75 projects, totalling 168 MW, to be completed by 1994. A breakdown of the projects is given in Table 2.

**Table 2: Contracted projects for electricity from renewable energy under Non-Fossil Fuel Obligation (1990)**

Number	Type	Capacity
7	Waste incineration	86 MW
25	Landfill gas	35.5 MW
9	Wind	28.4 MW
26	Hydro	11.6 MW
8	Biogas	6.5 MW
75		168 MW

These projects represent around 0.25% of current UK-installed capacity of around 65 GW. This may not seem much but further tranches are planned. The Department of Energy have invited proposals for a second tranche of 150-200 MW and envisage 1000 MW of installed capacity by 2000. This figure may well be increased if the government wishes to make a more positive response to concerns about global warming, although at the cost of increased electricity prices.

## Renewable energy technologies

First, waste utilisation can take various forms. Domestic refuse and certain industrial and forest wastes can be burnt in conventional boilers to produce electricity. Most of the waste is currently dumped in landfill sites and the energy available for use has been estimated as equivalent to 10 M tonnes of coal<sup>6</sup> per year. Second, some of the waste in landfill sites decays to produce methane. This can be captured and burnt in diesel engines or gas turbines to drive generators. Thirdly, biogas, such as methane from sewage works, can



similarly be burnt. All three sources are exploited to some degree at present, but scope for substantial expansion exists.

## Hydroelectricity

Hydroelectricity is the main source of renewable energy in the world and accounts for 20% of global electricity production.<sup>7</sup> Major new schemes, which often involve the flooding of large areas, are running into major environmental opposition and this will limit any increased contribution of hydroelectricity on a world basis. Within the UK, hydroelectricity accounts for around 1.5% of electricity generated, with most schemes to be found in Northern Scotland. There are few significant sites suitable for exploitation remaining in the UK although a number of small schemes have recently been put forward.

## Tidal barrage

The UK has the second best site in the world for tidal power — the Severn estuary. ETSU has estimated that electricity from a barrage across the estuary could cost 3.5p/kWh, although the use of a more realistic discount rate for the capital would double this figure.<sup>8</sup> The cost of the barrage has been put at £8 billion for an installed capacity of 8640 MW and it seems unlikely that the government would make a commitment of this size at present. The environmental acceptability of the scheme has also to be established.

There are, however, a number of smaller sites where costs appear comparable to those of the Severn, the largest being the Mersey. This is the subject of a current study and, if acceptable, the barrage could have an installed capacity of 500-600 MW and be operating in the 1990s.<sup>8</sup>

In broad terms it would be more sensible to develop one or more smaller sites first to gain experience. The Severn scheme might then emerge as a viable scheme for the early part of the next century — perhaps as an alternative to nuclear power if the government of the day decides further major alternatives to fossil-fuelled power are required.

## Wave power

The prospects for wave power appeared good in the early 1980s but were hit by an adverse ETSU report indicating high costs. These costs estimates have recently been challenged and ETSU are currently undertaking further studies. However, it is likely to be some time, at best, before the technology can demonstrate its engineering robustness in adverse conditions and its consequent ability to produce electricity at acceptable prices.

## Hot dry rocks

This is another technology in its infancy. Deep wells are drilled into hot granite and water pumped through to extract the heat. However, there are major technological problems to be overcome in the UK before prospects can be realistically judged.

## Solar power

Passive solar power — essentially making better use of the sun in the design of buildings — is likely to make an increasing contribution to our energy needs. Active solar power, prin-

cipally the technology of photovoltaics for turning sunlight directly into electricity, is well understood but costly at present. As costs come down it may increasingly be used in remote areas with strong sunlight, but it may be many years before it is economically attractive on a large scale in the UK.

## Wind power

The prospects for wind power were discussed in *Energy World* in September 1990.<sup>9</sup> The technology is the most mature of the 'new' renewable technologies. It has the advantage of being modular in design which allows small additions to be made to total capacity at different times and different sites. While the technology is likely to increase its contribution to electricity generation in the coming years, it has yet to be demonstrated that its widespread use throughout the country will meet public acceptability.

## Combined Heat and Power

The advantages of combined heat and power (CHP) have been well known to industry for many years. Industries with large and fairly constant steam demands have often had CHP schemes and the total installed electrical capacity is around 2 GW at present. While growth in CHP has been held back since the early 1970s by the CEB's surplus in generating capacity, and its consequent unwillingness to pay other than a low price for any surplus electricity, the privatisation of the electricity supply industry should allow new CHP schemes to compete more equally. Steam demand by industry has been falling, but the development of new technology with higher electricity/steam ratios should allow a substantial increase in total electrical capacity. Some schemes may also be viable for parts of the commercial sector where a sufficient load for steam exists. Hospitals may be one

possibility. However, the penetration of the domestic sector through district heating will be limited by the high costs of providing a distribution network and the low load factor for the heat.

From a CO<sub>2</sub> viewpoint, CHP can yield a saving of 20% to 30% compared to separate generations of electricity and steam, assuming like fuels are used in each case. Some efficiency in electricity generation is lost compared to a power-only scheme, but the overall efficiency for heat and power can be around 80%.

## Advanced coal-fired power

The development of a new generation of gas turbines is of benefit not just to gas-fired, but also to coal-fired, generation. To take good advantage of this the coal needs to be fully or partially gasified so that the coal gas can be burnt in the turbine. Full gasification systems are now being offered commercially with the Shell system, for example, giving an efficiency of around 40% on a gross CV basis compared to 37% for a traditional pulverised fuel system on the same basis.<sup>10</sup>

Partial gasification, which offers substantial cost and energy savings in the gasifier, may be the preferred route. With this approach there is a residual char left from the gasification process which is combusted in a separate boiler to contribute to the steam cycle. British Coal are conducting research into this 'Topping Cycle' arrangement and estimate that an efficiency of 44-45% can be achieved (on a gross CV basis).<sup>10</sup> This would give a 20% increase in efficiency and a 20% reduction of CO<sub>2</sub> emissions per unit of electricity compared to a traditional pulverised fuel system. Given that world reserves of coal are much greater than those of gas or oil, coal technologies are likely to have a major role to play in the future. Advances in efficiency can contribute substantially to limiting CO<sub>2</sub> emissions.

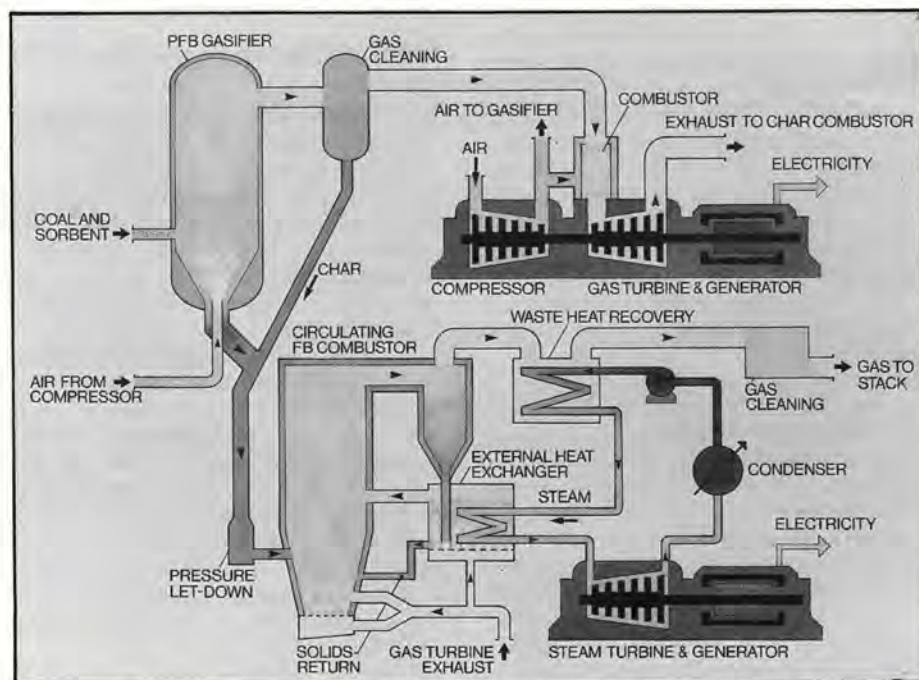


Fig 1: The Topping Cycle based on CFBC. Advanced coal-fired power stations can reduce CO<sub>2</sub> emissions by 20% through improved efficiency.



## CO<sub>2</sub> abatement

British Coal have been promoting a programme of research into CO<sub>2</sub> capture and disposal to be conducted under the auspices of the International Energy Agency. The initial three-year programme is being designed to assess the technological options, and the intention would be to follow this with the necessary development work to make the technology available for use.

Various options are available to scrub the CO<sub>2</sub> from flue gases such as physical or chemical scrubbing and cryogenic separation. Several options are also available for the ultimate disposal of the CO<sub>2</sub>: in disused oil or gas wells, in place of water in deep aquifers, or pumped at depth in the oceans. The first two of these are likely to be lower cost and should raise few environmental objections. The third would be more costly and would require detailed research to demonstrate environmental acceptability.

Only tentative cost estimates for CO<sub>2</sub> capture and disposal have been possible so far. However, the indications are that when combined with, say, advanced coal technologies, the costs of generation would be comparable with the most promising renewables and may be cheaper than nuclear.

## Conclusion

In summary, a variety of options exist for limiting CO<sub>2</sub> emissions from power generation in the UK. First, substantial savings

could be achieved by end users through energy efficiency and conservation, although government or European Community action would be required to bring about much of the savings. On the supply side the use of gas-fired CCGTs can reduce emissions of CO<sub>2</sub> per unit of electricity by 50% (compared to existing coal-fired stations). The addition of gas turbines to the front ends of existing power stations, on the other hand, could yield additional generation for little or no additional CO<sub>2</sub>.

Both options are currently attractive; the extent to which they can contribute will depend on the availability and price of substantial additional supplies of gas. CHP is also attractive, offering a 20% to 30% reduction in CO<sub>2</sub> emissions compared to separate generation, other than savings achieved via fuel switching.

Advanced coal-fired generation can yield CO<sub>2</sub> savings of 20% due to improvements in efficiency. Finally, CO<sub>2</sub> capture and disposal may become an option in the long term and could be preferable to nuclear power.

## Acknowledgement

The author would like to thank British Coal for permission to publish this article. The views expressed are those of the author and not necessarily those of British Coal.

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# ENERGY INVESTMENT: LIMITING THE RISK

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**MONDAY, 24 JUNE 1991**

Energy prices over the last two decades have shown abrupt and short-term changes, yet the investment pattern required to maintain assured supplies has to be based upon long-term assessments.

High prices in the late 70s caused high investment in energy resources away from the Middle East. The low oil prices of the 80s — coupled with these earlier investments — created a significant reduction in investment which, even without considering the impact of the Gulf Crisis, will have a tremendous effect on availabilities of all energy in the mid 90s.

Industry and transport need to have adequate supplies of energy at prices which will undoubtedly have to rise in real terms but at steady and relatively predictable rates.

This seminar will interest: economists, environmentalists and energy experts who need to analyse the management, financial and physical problems which will have to be considered in long range energy supply planning. It will be of great relevance to those in the energy supply business, generators and manufacturers.

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(Managing Director, BP Energy Ltd)

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at

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Office . . . . . Signature . . . . .



## A need for change

**'The Energy Alternative'**

by **Walter C Patterson**

**Boxtree, 1990**

**186pp, £16.99**

This book demonstrates the disastrous consequences of our postwar national energy policy which has served the wish of the suppliers to sell more energy, rather than the wish of the consumers to satisfy their real needs using as little energy as possible. We only spent proper money on fuel economy in wartime or after a sudden shock such as in 1973. At all other times we have been strongly persuaded to use more.

When I was a member of the Advisory Committee on Fuel and Power (ACORD) in the 1960s we were firmly told that we were only advisory, whenever we tried to suggest reductions in energy consumption. Prof Beér had the same experience later.

The installed capacity for electricity generation in the UK is about 1kW/cap, and the industry asks for more! In the richer countries we use the energy equivalent of 34bbl oil/cap an (abbreviation for annum) much of it in our vehicles. Patterson writes: "An average US household used electricity at a rate of about 360W/person and fuel at about 1140W. An equivalent all-electric US household, getting the same services by using the most efficient end-use technologies available even in 1982/83, would use only 328W/person — less than a quarter as much" (p105).

Chapter 9 'Power to the People' stresses the disastrous consequences of the fact that Third World planners have since the 1950s copied our careless attitude to energy. They have built skyscrapers needing fuel and electricity just to make them habitable, they have built GW power stations, and giant dams to make electricity that people cannot afford, and the traffic jams in their towns are often as bad as ours. "The enormous sums of money used to expand electricity supplies in Third World countries would yield far greater returns if devoted to high efficiency end-use hardware" (p153).

This is why I am devoting much of my remaining energy to trying to see whether we cannot provide all the essential benefits of modern engineering to rural Africans with 20W of electricity and 3bbl oil equivalent per capita.

An important way of getting more user benefits for less energy input in the developed countries is combined heat and power (CHP) in which Britain has been particularly laggard, probably because those who first drew up the terms of nationalisation did not understand the second law of thermodynamics and told the CEBG to sell electricity rather than energy.

Britain has also been laggard in renewables, fluidised bed combustion, and in using domestic heating instead of insulation. We have remained wedded to GW power stations longer than other countries, but at last we are beginning to see the error of our ways.

"Until the late 1970s, electric utilities almost invariably assumed that a bigger power station was cheaper and more efficient... they usually proved in practice to be anything but" (p121).

"British winds carry more concentrated energy than anywhere else in Europe: wind energy using proven designs could provide the cheapest energy available" (p141).

Wave energy was considered in 1973 the most promising of all the energy options (p137) but "In the 1980s the Government's Advisory Committee on Research and Development for Fuel and Power, for reasons that have never been adequately explained, recommended that the program be abandoned."

"According to the energy tradition, we are trapped in a rut that must lead inevitably to catastrophe" (p169).

*Prof M W Thring*

## Wind on the move

**'Wind Energy Conversion 1990'**

Edited by **T D Davies, J A Halliday**

and **J P Palutikof**

**Mechanical Engineering Publications 1990**

**346pp, £70.00 (UK); plus 10 per cent (overseas)**

The scientific and engineering literature on wind energy is found mainly in the form of conference papers. For the United Kingdom, some of the most significant reference volumes are the Proceedings of the Annual Conferences of the British Wind Energy Association. These books are nicely produced from the authors' own camera ready copy; they are A4 bound in hard covers and they are value for money. The 1990 volume contains around 50 fairly short papers which between them provide an excellent view of the present wind energy scene.

The book goes in at the deep end, starting with 'Electricity Privatisation and its Implications for Wind Energy,' by Peter Musgrove. He draws the encouraging conclusion that "wind farms on good windy sites can compete with 1000 MW scale conventional power stations (whether coal or nuclear fuelled). The wind farms, moreover, do not contribute any damaging pollutants into the environment: no carbon dioxide emissions; no acid rain gases; and no nuclear waste."

Unfortunately, topsy-turvy economics apply and CEBG power plant worth £12,600 million (according to their own 1988/89 Annual Report), with a replacement cost of £22,300 million, is to be sold off for only £3,500 million. This massive subsidy of the existing electricity system cannot be competed with unless wind, too, is subsidised and that seems to be the logic of the Non-Fossil Fuel Obligation, ensuring that a premium price is paid for tranches of wind energy.

Most of the papers in this volume are more specialised, concentrating on the performances of various wind farms, individual wind turbines, components, measurement techniques, modelling, analysis, aerodynamics, wind regimes, systems, planning constraints and many detailed aspects of generating power from the wind with modern technology.

If there is anyone in the energy field who is still inclined to scoff at the prospects for wind energy, they will do well to read this book for its wealth of detail on recent advances. All

those seriously interested in wind energy will certainly want to do so.

*Prof D T Swift-Hook*

## More to come?

**'Market Mechanisms for Pollution Control: Impacts on the Coal Industry'**

by **Jan L Vernon**

**IEA Coal Research, 1990**

**38pp, £60.00 (£180.00 to non-**

**member countries of IEA Coal Research)**

This report examines the use of market mechanisms for pollution control. That is, regulatory approaches such as taxes, subsidies and market creation which harness the power of the market to modify consumption and production patterns so that they are more environmentally benign. The focus of the review is on market mechanisms with potential impacts on the coal industry.

Jan Vernon reviews the market mechanisms that are currently operating. She compares their effectiveness and advantages with traditional regulations and standards. Most current market mechanisms aim to raise revenue for specific purposes, such as investment in central treatment of pollution, rather than aiming at changing polluters' behaviour. It is concluded that despite these limitations, governments have found market mechanisms useful to give flexibility to regulations and standards and to speed their implementation.

Section 4 of the report is an evaluation of the proposals for new market mechanisms. The potentially significant impacts on the prospects for coal are also evaluated. The main proposals that are analysed by the author relate particularly to the control of carbon dioxide and acid rain.

In conclusion I feel that this report is a good appetiser. It flags up several key subject areas where debate and policy formation will take place during the next few years. I hope that IEA Coal Research develop the issues further in future publications.

*Dr Andrew W Cox*

## Recently published

**'New Prospects for Methanol Fuel or Chemical'**

by **John C Fahy**

Financial Times Business Information, 1990, 115pp, £215 (UK); £225 (overseas); (incl p&p).

**'IAEA Yearbook 1990'**

International Atomic Energy Agency, 1990, 371pp, 600 Austrian Sch.

**A Customers Guide to Specifying Chimneys**

The International Committee of Industrial Chimneys (CICIND), 1990, 20pp, £9.00 (incl p&p).



## More thoughts on the future of the Institute

Sir,

I have considerable sympathy with the views of Simon A Wilce published in *Energy World*, November 1990. However, I believe it is worth noting the progress the Institute has made in recent years, as well as seeking views as to what the Engineering Council could and possibly should do for the entire engineering profession.

Over three years ago the then President established a working party to seek out views and opportunities which we could harness to enhance our image, our services to members, and our position as a prestigious learned society at the very heart of the energy scene. Indeed, an entire meeting of Council was devoted to this also, with syndicates addressing key issues and reporting back, most enthusiastically.

Essentially the key conclusions are centred around the need for the Institute to enhance its income, as well as spending a smaller proportion on administrative activities, however essential they might be, and a much larger proportion on primary or line activities contributing to the purposes for which the Institute was founded. These include publications, conferences, education, taking a more active involvement in national and international issues and so on. Not only are some of these income producing, but they are also promotional, and that in turn should lead to more applications for membership, the primary source of our income.

As many are aware, much of this has happened. We have a new General Secretary, Colin Rigg, who is also a member of the Institute in his own right. The presentation of *Energy World* has improved beyond recognition. The conference organisation has been strengthened and some excellent conferences have been held. The Annual General Meeting also has been combined with a conference and many of our speakers have been both well-known and acknowledged authorities. Further, some of our administrative functions, such as accounts, have been streamlined and economies achieved. All of this is a huge credit to the Secretary and his team.

However, there is one area where we have not been able to achieve as much as we would desire and that is recruiting to membership. We all know this is a tough issue, particularly for the younger individuals with possibly bigger demands on smaller funds. The Membership Committee and many others are working away at this, but the numbers available today also have been reduced both by the decline in the birthrate that began in the 1960s, and the reduced numbers entering the energy professions. Our ambitions of even three years ago towards increasing membership undoubtedly were too large, so we need to seek alternatives.

Personally, and until The Engineering Council or similar body provides a lead, I favour independence and continued cost reduction of administrative functions and continued enhancement of services to

members and promotional activities. Sharing premises with another institution, including the possibility of joint administrative functions such as subscription collection, could help. And if that is not enough, then a merger may be a solution.

Like Mr Wilce, I believe we have a great deal of synergy with the IChemE but we also have similar synergy with Gas, Metals, Nuclear and other such groups. There are many options worthy of pursuit, but overall the engineering professions badly need leadership towards solving both our problem, and similar problems amongst others. A solution which will preserve our independence of purpose, but greatly reduce our administrative and overhead costs would be ideal.

Hopefully, development of a solution is a role The Engineering Council will address before long. Indeed, I know many considered it to be their prime original purpose.

A possible solution might be a pyramid, with the Fellowship of Engineering at the very top, providing overall policy and broad direction for the engineering professions. The next layer would be The Engineering Council, there to undertake the entire administrative functions for all, in a thoroughly professional and cost effective manner. Beneath them in a third and final layer of the pyramid, would be the mass of existing institutions, each operating independently in their own field of expertise, jointly or in groups where it is relevant and each voluntarily agreeing so to do, freed from their current administrative and overhead functions, which have been, in my view, the root cause of the current difficult situation for us and for others.

To achieve this we need a lead or catalyst at a senior level from an influential source. Is it The Engineering Council? The Fellowship of Engineering? Or both? Or others? And above all will they be prepared to do it?

**Michael C Roberts**

(Fellow & Vice President)  
London

Sir,

I refer to the letter of Mr Wilce, 'The Future of the Institute' (*Energy World*, November, 1990).

It could be argued when OPEC began to increase the price of oil rapidly at the start of the 1970s, they actually did the world a favour by bringing about a realisation that energy supplies were not inexhaustible, and that one day, in the not too distant future, they were going to run out.

Decades of cheap and stable oil and coal prices lulled users into a false sense of security with regard to cost, and designers into a partial disregard for energy conversion in everything from cars to buildings. Many buildings built in the 1960s could be considered thermally transparent in relation to modern buildings. Heating and ventilation systems lacked any degree of sophisticated control or heat recovery systems. The use and production of electricity could now be considered in terms of pure

waste. The production of electricity from a base fuel involves the simple wastage of more than 60% of the calorific value of the base fuel in the cooling systems of the generating station. With hindsight it is easy to criticise the design of very large scale power stations sited away from urban centres which every day dump huge amounts of wasted heat into the atmosphere. However, no argument can justify the continued heat wastage implicit in present generation policies and methods.

The rapid rise in fuel costs hurts both industrial and domestic users. Energy assumed a greater role in company operating costs and, consequently, required the company to raise prices or increase production and sales in order to maintain profit levels. The doctrine of energy conservation assumed a rapid level of importance. However, this was not for the future, but more in terms of fuel saving in order to reduce fuel bills and save money. It became apparent to the industrial user, by saving energy you could reduce your operating costs and increase your profits without any necessary increase in production and sales. The domestic user too could benefit by reducing their energy use and so leave themselves more disposable income.

Since 1973, two painful bouts of inflation and recession have shown what the Middle East grip on world oil supplies can do to disrupt the world economy. However, as the recent Gulf crisis has shown, the West has done very little to protect itself economically from such problems. In a little over a month the price of oil increased rapidly from \$16 to just over \$29 per barrel. This could herald the start of another serious recession. How much worse could this crisis be if it were not for North Sea oil, and what if it had happened in 10 or 20 years from now, when North Sea oil begins to dry up. The West needs to take action now, or this myopic view of the end of the twentieth century will be looked upon by the next generation as too little too late.

Energy management is now firmly established and the production and use of energy is assuming political importance in terms of 'green' issues. Energy conservation could now be considered to be moving into a second stage, that is, towards conservation in the true sense of conserving energy sources for the future and, in so doing, aiding other issues such as pollution and protection of the environment. It is now essential that every joule of energy extracted from a fuel be utilised in the most efficient way with the minimum amount of under-utilisation as possible.

To this end the Institute has a tremendous role to play. The wealth and depth of knowledge contained within the Institute is, in itself, an important resource available to any government which wishes to and indeed, should, use it. Consequently, I believe the Institute now has a duty to market itself in order to make sure the resource of its knowledge is utilised to the benefit of all, and in doing so to make sure the Institute emerges as a leader, which absorbs rather than merges with other institutes.

**Robert L Skinner**

(Associate Member)  
Hull



## Continuing education

A NATIONAL system to help engineers and technicians to update and develop their careers and to boost the performance of industrial companies is being launched by The Engineering Council.

The Council's plan for a national system to promote and encourage continuing education and training (CET) will be announced at a conference organised by the Careers Research and Advisory Centre (CRAC), in association with the Council, at City Conference Centre, London EC3, on March 19.

Denis Filer FEng, Director General, says that the rate of change of technology is so rapid that the extent to which engineers are able to develop their careers is crucial to the future of engineering in Britain. "More UK industry needs to make the choice to use CET positively as a means of raising overall quality and more individuals need to take it up to improve the breadth and quality of their careers," he said.

"Nearly 80% of the workforce in the year 2000 are already working now, so we cannot realistically expect that the skills currently available will be adequate to cover every technological or management change in the working lives of those individuals — the learning of new skills will be vital."

Key elements of the national system for CET were tested in a pilot scheme which was

supported by more than 70 industrial companies, many of which are continuing to develop their own schemes. With the help of a personal planner-style 'Career Manager' book, more than 1000 participating engineers and technicians took on responsibility, in partnership with their employers, for planning their CET needs.

## Green focus for young engineers competition

BUDDING 'green' engineers can win more than £5,000 in the 1991 Young Engineers for Britain competition. The environment is being highlighted in this year's competition by The Engineering Council, which organises this prestigious event.

Two environment prizes totalling £5,000 will be awarded to teams of pupils from schools entering the best projects which investigate engineering solutions to environmental problems.

Mr Denis Filer FEng, Director General of The Engineering Council, said: "We want to heighten the awareness in young people's minds of the engineering solutions to environmental problems and the Young Engineers for Britain competition is an ideal platform for the

display of their inventiveness in this area. It will also help to foster the environmentally caring image of engineers to the public."

The 1991 competition, which is now open for applications, aims to encourage young people to undertake engineering project work and to strengthen links between education and industry.

Entries are invited from young inventors aged 11 to 19 from schools, colleges and industry in the United Kingdom. Entries must be in by March 31, 1991. Regional finals will take place throughout the country in June and July.

The overall winner of the competition itself will be awarded the coveted 'Young Engineer for Britain 1991' title, a trophy for £1,250 for his or her school or organisation for the purchase of engineering equipment. Runners-up will receive prizes of study visits to companies in the United Kingdom and abroad, cash prizes up to £600 for themselves and their schools and the opportunity to discuss projects and career prospects with highly qualified people in the field of engineering.

The best project by a girl or team of girls will win the WISE (Women Into Science and Engineering) award and £500 from The Engineering Council.

The three principal sponsors of the competition are Lloyd's Register, British Gas plc and National Westminster Bank plc.

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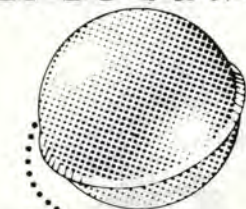
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## Methane control at Harworth

THE FIRST fully automatic methane drainage control system has been built by Westinghouse Systems for the new plant at Harworth Colliery.

The volume of methane gas pumped from the mine workings by the plant is expected to drive a 15 MW combined heat and power electrical generating station as well as providing space heating for the colliery.

The new plant has a total of eight exhausters pumps, with up to six in operation at any one time and at least two available for routine maintenance. The system starts and stops the exhausters pumps, with the duty cycle and number of running exhausters automatically controlled by the ratio of the air/methane gas mixture extracted from the mine. As well as controlling the operation of a variety of process valves, the system provides protection and safety features for individual exhausters and for the plant as a whole.

Previous applications of the Wesmind system, which was designed in close cooperation with British Coal engineers, have been skip control, shaft interlocking and push-button winding.

For further information, contact Westinghouse Systems Ltd, Mining Dept, PO Box 41, Chippenham, Wilts SN15 1JJ.

## Hospital energy saving

AN OXYGEN trim control system, the microprocessor-based Energyman, produced by Telegan, is helping to recover costs at St Helens Hospital in Merseyside. Fuel savings of up to 5% can be made using automatic oxygen control.

In addition to fuel energy efficiency, good oxygen trim control reduces noxious emissions, such as nitrogen oxides.

Oxygen levels are measured by the in-stack zirconia sensors and provide a signal to this method of pulsed control. A rapid and positive response to oxygen change is required to maintain optimum efficiency and this signal is fed to the fuel/air ratio control on the burners.

Further details from Telegan Ltd, Legion House, Godstone Road, Kenley, Surrey CR8 5JX.

## Fusion multiplexers for Japan

ERA-DESIGNED multiplexers have been supplied as part of a reflectometer system for Japan's Tokamak-60 reactor.

The Japan Atomic Energy Research Institute is one of several research labs competing in the race to develop, control and monitor experimental nuclear fusion reactors.

The multiplexers measure the electron density profile of the plasma confined in the Tokamak machine by launching swept frequency signals into the plasma to give the relative positions of the critical electron density layers. From these the density profile inside the reactor can be determined.

The two wideband millimetre multiplexers are used either as a

combining or a separating network for operation at frequencies between 22 GHz and 75 GHz.

The separator design incorporates two oversized waveguide multi-hole couplers which, when used in conjunction with tapered waveguide high-pass filters, divide the signals into three frequency bands (22 to 32 GHz, 33 to 49 GHz and 51 to 75 GHz).

ERA Technology have already supplied microwave and millimetre wave components and systems for the Joint European Torus reactor in England and for the Frascati Tokamak Upgrade reactor in Italy.

Further details from ERA Technology, Cleeve Road, Leatherhead, Surrey KT22 7SA.

## Forth Bridge centenary lights

JEL BUILDING Management Systems were awarded a contract to monitor lighting on the Forth Bridge towards the end of 1990, marking its centenary and making it the biggest outdoor illuminated structure in the world.

The JEL system switches all lights on and off and indicates if any light fittings have failed. This assists the work of the maintenance team servicing the bridge.

A network of standalone controllers are installed locally on the approaches to the bridge and the three cantilevers. These are linked via a communications cable to a Jelnet central station,

which allows the operator to switch the lights on and off at any time of the day or night. When shipping is passing through the coastguard can command the lights to be switched off via a telephone link with the JEL system.

Ten JEL units linked to current transformers switch and monitor the lighting controls on the bridge, while five unitary controllers which network onto the system have been installed on the approach viaducts.

Further details from JEL Building Management Systems Ltd, Thorn Security Ltd, Security House, Twickenham Road, Feltham, Middlesex TW13 6JQ.



The 100-year old Forth Bridge.

## Gas turbine for Mucking

LANDFILL gas generated at a landfill site in Mucking, Essex, will be used solely to power a generator using a gas turbine, both supplied by Centrax Gas Turbines of Newton Abbot.

The unit will produce 3.7 MW of electricity at 11 kV for supply to the regional electricity company as well as fulfilling the need to dispose of the gas safely. For more than 50 years the 800-acre site at Mucking has received up to half a million tonnes of London's domestic waste annually, which is transported from inner London by barge.

Since 1985 a horizontal well collection system has been constructed within the site to draw off the gas, and trials have indicated yields of up to 750 therms per hour, making ample supplies for the gas turbine.

For further information contact Centrax Gas Turbine Division, Shaldon Road, Newton Abbot, Devon TQ12 4SQ.

## Energy priority low, says survey

BRITAIN'S ENERGY bill is higher than it need be because of poorly informed management and could be costing industry and the taxpayer millions. So says a survey published last December by Enterprise Information Systems (EIS), which revealed a lack of awareness and investment in energy management procedures and systems that could significantly reduce overheads.

The Welsh-based software company, which produces energy management information systems (EMIS), interviewed finance directors and chief executives of more than 300 companies and public sector organisations throughout the UK. A quarter of the total organisations interviewed (23 per cent private, 26 per cent public sector) had no EMIS at all. Of those that did, over 70 per cent had opted for the cheapest and most basic systems available, usually manual and costing less than £25,000. But the survey also revealed an interesting polarisation among users — with 19 per cent spending over £100,000 on software, but very little in between this upper end and the majority of users who specified lower-level systems.



## February 1991

**Annual Dinner & Dance**

The Chemical Engineering & Fuel Technology Society, University of Sheffield, 23 February, Sheffield.

Details from Pippa Linsell, The Chemical Engineering Building, Sheffield S1 3JD. Tel: 0742 768555, ext: 5339.

**Profit the Environment**

Conference, 27-28 February, London.

Details from RMDP Ltd, 61-3 Ship Street, Brighton, East Sussex BN1 1AE. Tel: 0273 722687; fax: 0273 821463.

## March 1991

**Sensor-guided Control of a Robot Vehicle**

Lecture, 19 March, London. Details from The Fellowship of Engineering, 2 Little Smith Street, London SW1P 3DL. Tel: 071 222 2688.

**IOE South Coast Branch AGM**

20 March, 7 pm on the Steamship 'Shieldhall', Ocean Village, Southampton.

**Desulphurisation II**

Conference, 20 March, Sheffield. Details from the IChemE Conference Section, tel: 0788 578214.

**Electricity at Work Regulations**

Lecture, 12 March, Liverpool. Details from Tony Deeson, General Secretary, The Institute of Engineers & Technicians, 100 Grove Vale, London SE22 8DR. Tel: 081 693 1255.

**Robust Control System Design Using H-Infinity and Related Methods**

Two-day symposium, 21-22 March 1991, Cambridge. Details from Angela Lonergan, The Institute of Measurement & Control, 87 Gower Street, London WC1E 6AA.

**Turbomachines: Condition Diagnosis, Fault Early Detection, Service Life Monitoring**

Conference, 21-22 March 1991, Aachen, FR Germany. Details from VDI-Gesellschaft Energietechnik, Postfach 11 39, D-4000 Düsseldorf 1. Tel: \*211/6214 363.

## April 1991

**Advances in Particulate Technology**

Symposium, 15-17 April, Guildford, UK.

Details from Mrs Jean Libaert, Dept of Chemical & Process Engineering, University of Surrey, Guildford, GU2 5XH.

**16th International Conference on Coal & Slurry Technologies**

Three day conference, 22-25 April, Florida USA.

Details from Barbara Sakkestad, Coal & Slurry Technology Association, 1156 Fifteenth Street, NW, Suite 525, Washington DC 20005, USA.

**CIBSE National Conference**

7-9 April, Canterbury, Kent. Details from CIBSE Member Services Dept, Delta House, 222 Balham High Road, London SW12 9BS. Tel: 081 675 5211.

**The Impact and Mitigation of Oil & Gas Activities in Coastal Environments: Gulf of Mexico, North Sea and Alaska**

International seminar, April, Louisiana, USA.

Details from Dr D Davis, Louisiana Geological Survey, Box G, Baton Rouge, Louisiana, 70893, USA. Tel: (504) 388 5320 or Lynda Kingham, Centre for Environmental Planning and Management, University of Aberdeen AB2 3DS. Tel: 0224 272884.

**Discharge — Your Obligations**

Conference, 4-5 April, Coventry. Details from the Conference Office, Box 12, Barclays Venture Centre, University of Warwick Science Park, Coventry CV4 7EZ. Tel: 0203 692443.

**11th CIRED Conference (International Conference of Electricity Distribution)**

22-26 April, Liège, Belgium. Details from Organizing Committee of CIRED 1991, c/o AIM — Mrs Ch Lacrosse, rue Saint-Gilles, 31, B-4000, Liège, Belgium. Tel: +32 41 22.29.46.

**International Symposium on Alcohol Fuels**

9-12 April, Firenze, Italy. Details from Symposium Secretariat, ISAF-91, ECO-FUEL (AgipPetroli Sector), Viale Brenta 15, 20139 Milano, Italy. Tel: 39 2 520.21923.

**The Management of Spent Nuclear Fuel**

International seminar, 29-30 April, London.

Details from Liz Hide, IBC Technical Services Ltd. Tel: 071 236 4080.

## May 1991

**Petroleum Group's 2nd Annual Dinner**

9 May, London. Details from Heidie Gould. Tel: 071 287 1433.

**24th ISATA**

Conference, 20-24 May, Florence, Italy.

Details from ISATA, 42 Lloyd Park Avenue, Croydon CR0 5SB. Tel: 081 681 3069.

**Classification of Hazardous Areas Containing Potentially Explosive Atmospheres**

Tutorial Day, 21 May, Chester. Details from Sira Communications Ltd, South Hill, Chislehurst, Kent BR7 5EH. Tel: 081 467 2636, ext: 373.

**Applications of Information Technology**

Conference, 29-31 May 1991, Stratford upon Avon, England. Details from The Conference Office, Institution of Civil Engineers, 1-7 Great George Street, London SW1P 3AA.

**Environmental Issues — Their likely impact on the Metals Processing and User Industries**

International conference, 15-17

May 1991, Amsterdam, The Netherlands.

Details from Margaret Swadling, Conference Organiser, BNF Metals Technology Centre, Wantage Business Park, Denchworth Road, Wantage, Oxfordshire OX12 9BJ. Tel: 0235 772992, tx: 837166, fax: 0235 771144.

## June 1991

**Engineering Trade Mission**

7-21 June, Bangkok and Kuala Lumpur.

Details from Anna Small, Engineering Industries Association, 16 Dartmouth Street, London SW1H 9BL. Tel: 071 222 2367.

**RoSPA International Safety & Health Exhibition & Congress**

18-20 June, Birmingham. Details from Glenis Kendall, RoSPA, Cannon House, The Priory Queensway, Birmingham B4 6BS. Tel: 021 200 2461.

**European Reliability 91**

International conference, 10-12 June 1991, London.

Details from Barbara White, Conference Organiser, AEA Technology, Wigshaw Lane Culcheth, Warrington WA3 4NE.

**African Mining 91**

International conference, 10-12 June 1991, Harare, Zimbabwe.

Details from The Conference Office, The Institution of Mining & Metallurgy, 44 Portland Place, London W1N 4BR.

**Power Supply Europe**

Exhibition, 18-21 June 1991, Birmingham, England.

Details from Chris Timmins, Swan House Special Events Ltd, Holly Road, Hampton Hill, Middlesex TW12 1PZ.

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# INSTITUTE OF ENERGY CONFERENCES



The following programme is currently being organised by The Institute of Energy.

**For further details please contact Judith Higgins or Jill Leigh on 071-580 0008.**

- |                |   |
|----------------|---|
| 13 March       | <b>WHERE ARE WE NOW ON NUCLEAR POWER?</b><br>Venue: The Conference Forum<br>Chairman: Mr C E Pugh CBE (Institute of Energy)   |
| 30 April-1 May | <b>FIRE &amp; EXPLOSION HAZARDS: ENERGY UTILISATION</b><br>Venue: Fire Service College, Gloucestershire<br>Chairman: Mr P G Redpath (British Steel)   |
| 16-17 May      | <b>INSTITUTE OF ENERGY ANNUAL CONFERENCE</b><br><b>CHP: CREATING HIGHER PROFITS</b><br>Venue: The Mount Royal Hotel<br>Chairman: Dr D N Fricker (British Gas)                                   |
| 12 June        | <b>SCRUBBING OR SWITCHING:</b><br><b>MEETING THE DIRECTIVE ON ACID RAIN</b><br>Venue: Millbank Conference Suite, London SW1<br>Chairman: Mr D M Willis (Institute of Energy)                    |
| 24 June        | <b>ENERGY INVESTMENT: LIMITING THE RISK</b><br>Venue: CBI Conference Centre, London WC1<br>Chairman: Mr D M Willis (Institute of Energy)  |
| 9 October      | <b>ENERGY FROM WASTE</b> (provisional title)<br>Venue: CBI Conference Centre, London WC1<br>Chairman: Mr B Lees (Institute of Energy)   |
| 12 November    | <b>2nd Conference on ENERGY STATISTICS</b><br>Venue: The Royal Society<br>Chairman: Dr A W Cox  |
| 11-12 December | <b>5th International Fluidised Bed Combustion Conference</b><br><b>FBC TECHNOLOGY TO MEET THE ENVIRONMENTAL CHALLENGE</b><br>Venue: To be confirmed<br>Chairman: Mr J S Harrison (British Coal) |

## Conferences co-sponsored by The Institute of Energy

- |             |  |
|-------------|--|
| 20-25 March | <b>2nd International Conference on Desulphurisation</b><br>Contact: Institution of Chemical Engineers on 0788-578214 |
| 5 April     | <b>Gas 2000</b><br>Contact: Combustion Engineering Association on 0685-879119/874201                                 |
| 15-17 April | <b>Engineering For Profit From Waste</b><br>Contact: Institution of Mechanical Engineers on 071-222 7899             |
| 21 May      | <b>New Technologies For Air Pollution Reduction</b><br>Contact: Pauline Sim on 0494-713664                           |
| 18 June     | <b>Practical Solar Energy — New Opportunities in Europe</b><br>Contact: The Solar Energy Society on 071-333 4314     |

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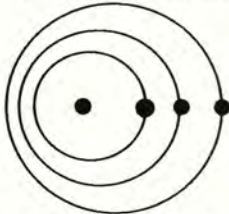
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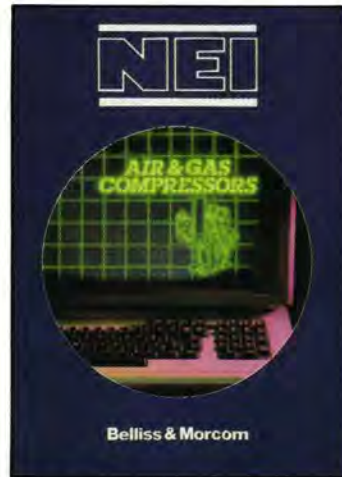
For further information please contact:



Scottish Energy Centre

**Mr E BODDIE (Director)**  
Scottish Energy Centre  
Napier Polytechnic of  
Edinburgh  
Colinton Road  
Edinburgh EH10 5DT  
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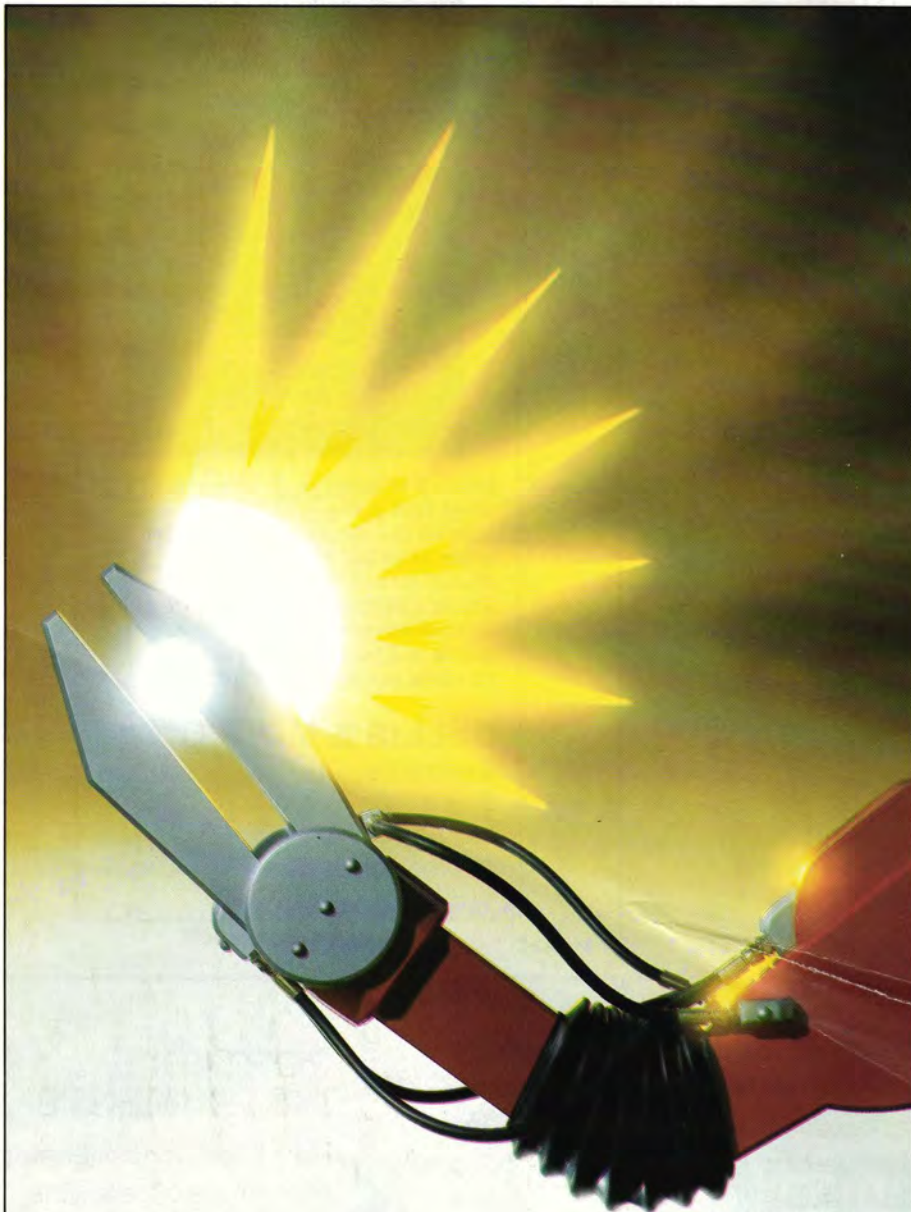
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