

ENERGY WORLD

The magazine of The Institute of Energy

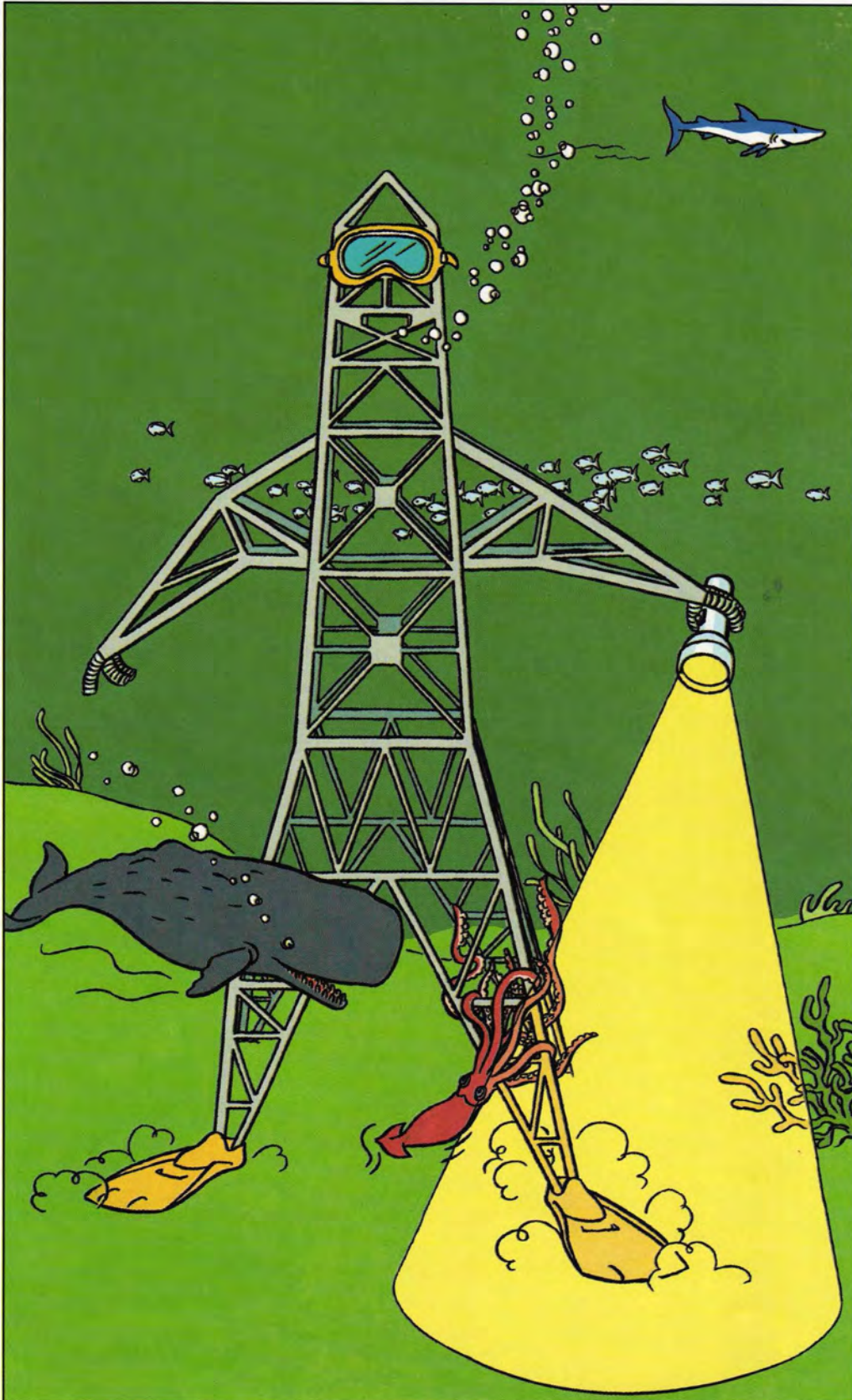


Mumbai
June

INSIDE THIS ISSUE:
Features on
methane and
fuel cells

To provide Britain with electricity,
we're constantly exploring new fields.

This one is in the North Sea.



The spirit of Star Trek lives on. For we at National Power are on a mission. To explore new means of generating electricity. To seek out new fuels. To boldly go where no electricity generating company has gone before. This journey of discovery means we're planning to build one of the UK's largest Waste-to-Energy plants. A facility that will produce clean electricity by burning both domestic and commercial rubbish. We are helping to develop Britain's first commercial wind farm. Most encouraging of all, it's meant we're exploiting gas as a fuel for generating electricity. Combined Cycle Gas Turbines (CCGT's) are the power stations of the future. They are much cheaper and quicker to build than traditional coal-fired stations. They burn fuel 30% more efficiently. And they are also much cleaner. Producing 60% less CO₂ and 99% less sulphur dioxide than existing coal burning plants. Of course, the potential of gas requires secure supplies of the fuel itself. So we've bought the output of two entire gas fields. And there is a lot more in the pipeline. Who knows where our journey of discovery will lead next? All we can say is that if there are new ways to generate electricity, we'll explore them.

National Power.
Ahead of
current thinking.

ENERGY WORLD



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COVER

This month's cover shows the 'Römerbrücke' district heating power station, which belongs to the Saarbrücken Town Utility in Germany, and is situated on the banks of the River Saar.

Saarbrücken was the only local European community to receive the UNO Environmental Award during the recent Earth Summit in Rio de Janeiro. The award is seen as recognition of the Römerbrücke plant.

The coal-fired plant was supplied by ABB Kraftwerke AG, Mannheim. It incorporates circulating fluidised bed technology, and supplies the local grid with heat and power. In 1989 the plant won US *Power* magazine's Environmental Protection Award.

Photo courtesy of ABB Kraftwerke AG.



Do we still need a Department of Energy?

AS signalled in the Conservative Election Manifesto, the Department of Energy (DEn) is abolished, its responsibilities taken over by the Department of Trade and Industry (DTI) and the Department of the Environment (DoE). There will be no shortage of critics prepared to argue that the change implies a down grading in energy policy amongst the new Government's priorities. The environmental lobby will also express dismay as it fears that it indicates the relegation of a much needed strategy for improved energy efficiency and reduced global emissions.

Before we join this widespread condemnation, we need to assess what are the important energy policy issues which government should address; how effective the Department has been over its 20-year life and whether its role can be as well performed under the Whitehall reshuffle.

The Department's principal function has been the management, as shareholder, of the nationalised monopoly gas, electricity and coal industries, with also a part state-owned offshore oil industry, added in the 1970s. The change of government in 1979 brought a radical policy reversal with a new priority — the creation of competitive privatised energy markets. Now only British Coal remains under Departmental control and its pending privatisation would certainly not justify the retention of a full government department.

A critical analysis of the DEn's divestment of British Gas obliges one to question whether the DTI would not have made a better job of it. Setting it up as a privatised monopoly, with a limited regulatory regime, has revealed the ever more evident, unsatisfactory features which have created problems for OFGAS, the Office of Fair Trading (OFT) and, above all, consumers. The duopoly structure designed for the CEBG's privatisation has also proved less than ideal, and the promised competitive market in electricity has not yet materialised.

The inherent bias within the DEn culture towards energy supply, has resulted in imbalances in policy making. The best interests of consumers have been given less priority than servicing the demands of the energy supply industries. One wonders, if these privatisations had been devised by the DTI, which also includes responsibility for consumer affairs, the Office of Fair Trading and the Monopolies and Mergers Commission, would not a more satisfactory competitive structure have been devised from the outset?

The DEn management of the coal industry has also left an impression of short-term expediency rather than a longer-term strategy. Plenty of taxpayer's cash has been extracted from the Treasury and shovelled in. But, have these enormous sums over the years given us value for money? More emphasis earlier on should have been given to improving management. The subsidies might then have given the industry a fighting chance of holding more of its market, in anticipation of a privatised electricity industry.

One has to ask if, within the DTI, British Coal would not have fared better. More support for investment in the critically important clean-coal burning technologies might have been provided, rather than neglected by the DEn. Under the DTI British Coal might also have had a stronger voice in Brussels,

complaining more robustly about unfair subsidies for much higher cost coal production in Germany, while our lower cost pits are closed.

It is interesting to speculate on how the DTI with responsibilities over a whole range of UK industry, would have developed policy in the nuclear industry. Would the muddle, indecision and lack of strategy have been allowed to persist for so long? One suspects the nuclear industry would have been forced to get its act together while there was still some prospect of making a competitive contribution to our energy supplies. With the fudge on costs and the cosy relationship with its customer, the CEBG, would probably have been exposed long before the plug finally had to be pulled, when it became evident that the nuclear power stations could not be privatised.

The DEn's role in monitoring the offshore oil industry could slot well into the DTI. The licensing function is primarily to ensure fair play and to help the UK offshore supplies industry. Competition downstream, at the product's end, is already the responsibility of OFT. Meanwhile, EC energy policy, under the European Single Act, overrides sovereignty by member states over depletion policy, strategic reserves and diversity and security of energy supply. The proposed EC Utilities Directive will remove conditions on free movement of gas and electricity, opening up European grids for third-party access. No UK government would be able to prohibit imports or exports of oil or gas within the Community. So the Department of Energy's role in these areas of former policy become irrelevant.

It seems likely that the most important energy issue on the political agenda over the coming years will be the environmental constraints. If we are to meet agreed international global emission targets, some more vigorous policy initiatives will be required. We need stronger incentives to promote energy efficiency, reduce emissions particularly from road transport, and raise thermal efficiency of power generation by using more of the waste heat, by developing combined heat and power with district heating.

The DoE now takes over this area of policy. Although splitting the DEn's responsibilities in this way suggests a possible weakening in the co-ordination of an energy strategy, we should acknowledge that the DoE has in recent years assumed stronger initiatives over the DEn's demand-side policies. The White Paper *This Common Inheritance* outlined our commitment to reduced pollution and higher priorities to promote energy efficiency. So a full transfer of environmental energy policy may prove advantageous.

Under the thumb of the DEn, the Energy Efficiency Office has had insufficient independence or muscle. Transferred to a lead government department, responsible for co-ordinating environmental improvement throughout government, and with a higher pecking order over other departments, we could see a more effective overall strategy and a much needed higher priority for the promotion of environmentally cleaner energy. If the lead now comes from the Department of the Environment, there is a better prospect that other government departments, such as Transport, will become more involved.



Much of the running in energy policy will be assumed by agreed Community action, in particular the proposed energy/carbon taxes, the Single European Act opening up third-party access across European grids, the Energy Charter and responsibility for security and diversity of supply. Our voice will have to be more powerfully represented in Brussels, on such vital issues, where national sovereignty is overridden in the overall interest of a competitive European energy market. UK policy, now shared between two major government departments should ensure that our voice is more adequately represented where it matters.

So will the Department of Energy be missed? Clearly one could argue that the Department is going, not because it has worked itself out of a job, but because the strategic challenges are today even more important than before. The environmental dimension is likely to impact increasingly on energy policy and more decisions will be required within a wider European context. Which department does it is less relevant than whether government as a whole grasps the priority issues involved.

Peter Rost
Chairman, Major Energy Users' Council

UK COAL '92 - OPPORTUNITIES FOR TRADE

The Premier Conference and Trade Exhibition on the
Future of the UK Coal Industry and Opportunities for Trade

Thursday, 15 October 1992 - Cafe Royal, Regent Street, London

UK INDUSTRY & MARKETS

Chaired by: Colin Gubbins
Oil, Gas, Imported Coal Manager, PowerGen plc

- 9.00 **Introduction & Welcome Address**
Jim Harrison
President Elect, Institute of Energy
- 9.15 **Opening Address**
Timothy Eggar MP, Energy Minister
Department of Trade & Industry
- 9.25 **British Coal Scenario**
Neil Clarke
Chairman, British Coal
- 9.55 Discussion
- 10.10 Morning Coffee
- 10.40 **Implications for the UK**
Joint Presentation by:
David Feikert, National Union Mineworkers
Billy Etherington MP
Formerly Vice-President, North Eastern
National Union Mineworkers
- 11.10 **Contracts and Legal Implications**
Graham Marriott, Keir Mining
- 11.40 **The Prospects for the Industrial Coal Market**
Major Industrial User
- 12.10 Discussion
- 12.30 Luncheon

OPPORTUNITIES FOR TRADE

Chaired by: Keith McNair
Director - Fuel Management, National Power

- 1.30 **The International Market Perspective**
Vaughan Williams, Managing Director
BHP Minerals Europe Ltd
- 2.00 **Brokers' Debate**
Trans-shipment vs. UK Ports
Representatives from:
Galbraith's Ltd
Simpson Spence and Young Shipbrokers Ltd
Other major shipbrokers
- 3.10 Afternoon Tea
- 3.40 **Opportunities for French Ports & changes in Handling Conditions**
Joint presentation by:
P-Y. Reynaud, Freight Department Manager,
Port of Le Havre Authority
Pierre Joly, Head of Development
Port Autonome de Dunkerque
Discussion
- 4.30 **Closing Remarks & Personal View**
Crispian Hotson, Chief Executive
Ryan Group Limited
- 5.00 End of Conference

For further details, please contact:

The Institute of Energy, Conferences Department, 18 Devonshire Street, London, W1N 2AU
Tel: 071-580 0008 Fax: 071-580 4420



Finance survey on former Soviet Union

WESTERN energy companies are prepared to make significant investments to develop the vast energy reserves in the former Soviet Union, despite uncertainties caused by decentralisation, according to a recent survey.

The survey, commissioned by Ernst & Young, is thought to be the first of its kind and was undertaken in March by Consensus Research International, and sought the views of 25 leading energy companies worldwide on the future of the energy industries in the former Soviet Union.

Over 70% of the companies surveyed had or planned a pres-

ence in the area. Of these 50% favoured immediate investment. However, although the combined investment of four of the companies is likely to exceed \$4 billion, that of the remaining companies is unlikely to be greater than \$500 million.

Most of the companies said that the failed coup last August had not changed their views on the industries' potential, but the problems resulting from decentralisation and fragmentation have made the investment risk too high for many companies, and have limited the amount others are prepared to invest.

The European Energy Charter is perceived as important in reducing such risks and providing the orderly development to resources to the mutual benefit of both East and West. If the Charter is seen to be working effectively, levels of investment are likely to rise more rapidly, according to the survey.

The main geographical areas of interest to Western companies so far are Western Siberia and the Kazakhstan, where investment has been principally in oil and gas production, development and enhanced recovery projects.

Power for Nepal

IN THE run up to the elections in Nepal last year, the Congress party, who were voted into power, promised to bring electricity to every village within the next 15 years.

The task is a formidable one. Only 9% of the population currently have access to electricity, and these are almost all in urban areas. There are some 40,000 villages to reach, many up to 14 days walk from the nearest road, and existing plans to increase the grid's capacity are unlikely to keep pace with growing energy needs. An alternative strategy is clearly needed for rural areas.

Intermediate Technology (IT), the organisation founded on the ideas of Schmaker, has been working with local organisations in Nepal over the last nine years. They hope to be able to provide the building blocks for such a strategy.

Their micro-hydro programme has been operating in Nepal for several years, and IT hope that this decentralised approach to energy supply could provide the answer to the problem in remote rural areas.

Some of IT's most impressive schemes are to be found in the Mustang district, where local communities have successfully raised funds for installations which are now up and running and have the capacity for upgrading in the future.

The new Nepalese government is said to be receptive to new ideas and has set up a Task Force to advise on energy policies.

BNF support pan-European scheme

BRITISH Nuclear Fuels, Nuclear Electric and WS Atkins Project Management are among several UK companies supporting a pan-European certification programme for project managers.

The Association of Project Managers (APM) programme is expected to attract up to 1,000 applicants from a wide range of industries, including construction, power generation and telecommunications. The implementation of the certification programme will enable companies to use the qualification as a yardstick of competence in project management disciplines.

Mr Eggar's crusade

UK Energy Minister, Tim Eggar, has called for a 'new crusade' to speed the pace of energy liberalisation throughout the whole of Europe.

Mr Eggar was speaking at an Anglo-Norwegian conference held in London. He commented on the heavy emphasis placed on the free movement of goods and people, but the free movement of energy across national frontiers had, he said, continued to meet fierce resistance from a few powerful vested interests.

He went on to comment that there remains significant disparities in energy prices between EC member states, and that this situation is ultimately unsustainable within the context of the single market.

Efficiency — key weapon

IMPROVING energy efficiency is the world's key weapon in providing solutions to environmental pollution arising from energy supply. This was the message of the first international conference of the Watt Committee on Energy, held in Strasbourg in April.

Conference President, Prof Bernard Giovanni, of the University of Geneva commented: "There are many longer term solutions to meeting the world's energy requirements which have minimal environmental impact, but to be sure of avoiding global catastrophe, action to reduce harmful emissions must be taken immediately and the largest potential lies in improving energy efficiency."

The conference heard that half the energy currently used could be saved quite easily through a mix of measures. These include improving the performance of electrical appliances and heating systems, switching to energy efficient light bulbs, insulation and intelligent control systems.

Pipeline progress

CONSTRUCTION began in May on the long-distance gas pipeline MIDAL (Mitte-Deutschland-Anbindungs-Leitung), between Emden and Ludwigshafen in Germany.

The long-distance pipeline (about 640 km) is due to start operation in autumn 1993.

40-year joint venture

A UNIQUE 40-year joint venture was signed in May by the Republic of Kazakhstan's President Nursultan Nazarbaev and Chevron Corporation Chairman Kenneth T Derr. The historic documents paved the way for the development of the Tengiz and Korolev oil fields on the north-eastern Caspian Sea coast in western Kazakhstan.

The project foresees a potential peak oil production rate of over 700,000 bpd by 2010, making the venture the largest of its kind between a major republic of the Commonwealth of Independent States and a major multinational oil company.

The Tengiz field was discovered in 1979, and Korolev was discovered in 1986. Production began at Tengiz in 1991 and is currently about 60,000 barrels of oil per day. The Korolev field is expected to begin production in 1999.

Ethanol myth could be debunked

A WIDELY accepted assumption that adding ethanol to petrol causes it to evaporate faster and adds to air pollution may not be true, according to preliminary research by the US National Alternative Fuels Laboratory (NAFL).

The NAFL, part of the US Energy and Environmental Research Center at the University of North Dakota, has conducted a side-by-side comparison of an ethanol-blended petrol, unleaded petrol and unleaded petrol from the pump. The test revealed that ethanol-blended petrol consistently evaporated more slowly than unleaded petrol at 70°F.

Tests in Denver, Phoenix and other US cities have demonstrated that a 10% blend of ethanol and petrol can reduce carbon monoxide emissions by an average of 20%. In addition, research in St Louis and New York indicates that ethanol blended petrol can actually help reduce ozone emissions.

Ethanol's key advantage is that it is a renewable resource, unlike other oxygenates, such as methyl tertiary-butyl ether, which is derived from fossil fuels.



New cabinet post for science

THE ROYAL SOCIETY has welcomed the Government's new arrangements for science. Under these, central responsibility for science and technology policy will be taken by the Chancellor of the Duchy of Lancaster, acting on behalf of the Prime Minister and assisted by the Parliamentary Under-Secretary of State.

The Society believes that this move, and the creation of the Office of Science and Technology (OST), will resolve many of the shortcomings that existed previously. It demonstrates the Government's increased interest in science.

These developments are in line with the thinking of the Society's own Science Inquiry. They will enable four key weaknesses of the previous arrangements to be addressed:

- inadequate coordination of publicly funded research;
- lack of effective representation for science at Cabinet level;
- inadequate representation of

UK interests in international scientific fora, notably the European Community;

- unsatisfactory arrangements for handling major international scientific subscriptions.

The Society looks to the OST to play a pro-active coordinating role throughout UK R&D. It should have charge not only of the Science Budget of the former DES but also of an additional separately identifiable budget.

The Society has also called for a reassessment of existing advisory bodies such as ABRC and ACOST. The new structures now being set up will need the support of new advisory mechanisms.

The Society believes that most fundamental research should be associated with teaching. It therefore welcomes the continuation of the block grant system, by which the grant to universities can be used at their discretion for the joint support of teaching and research in the most economical and effective manner.

A burning issue

INCINERATORS will have to meet stricter environmental controls as they play a bigger role in disposing of the UK's waste, a leading law firm has warned.

Mr David Goodman of Hammond Suddards said there were question marks hanging over the future of current UK waste disposal methods.

Recycling was proving costly, laws were being prepared to prevent landfill of certain wastes, the mass dumping of sewage sludge at sea must stop by 1988, and chemical treatment is used for the disposal of less than ten per cent of hazardous materials.

However, Mr Goodman warned that the predicted rise in the incineration of waste was not without problems.

In the UK there are 34 municipal incinerators for domestic and commercial waste; four hazardous waste incinerators — but 900 clinical waste incinerators across the NHS.

Mr Goodman said the likely increase in applications for new incinerators across Britain in the next few years would be met by tough planning laws.

Very promising 1992 first quarter results from BG

DESPITE the warm weather in the UK and Canada, BG's performance in the first quarter of 1992 was reasonably encouraging. Continued growth was achieved in the tariff sector of the UK Gas Business. BG's Exploration and Production and Global Gas Businesses broadly maintained their profits in adverse trading conditions.

From a regulatory standpoint, BG have agreed with the Office of Fair Trading the terms and conditions for the release of gas to competitors. They have published a consultation document on transportation charging and, in accordance with our agreement, we are working to separate the assets and functions of the UK Gas Business into the Gas Trading and Gas Transportation activities.

Although the underlying business is strong, the combination of warm weather, low oil prices and increasing regulation will influence the results for the year.



The Coal Research Establishment, based in Gloucestershire, has equipped two mobile labs, like the one pictured above, with a sophisticated flue gas analysis system to enable industry to comply with EC directives on air quality and emissions.

The mobile labs provide customers with on-the-spot detailed analysis of emissions from combustion and process plants to help operators assess pollutant levels, identify potential problems and optimise plant efficiency.

Parliamentary lobby to save pits

AROUND 100 representatives from local authorities in Scotland, Wales, the North East, North West, Yorkshire and the Midlands lobbied parliament in May, calling for a moratorium on pit closures.

The call, which came from the all-party Coalfields Communities Campaign (CCC), follows the announcement in the Queen's Speech that the coal industry is to be privatised. CCC are particularly concerned about the NM Rothschild report, leaked last year, which concluded that the industry could shrink to as few as 14 pits. Their concern is heightened by the lack of progress in the current negotiations on new contracts with National Power and PowerGen. Without these contracts — the current ones end in March 1993 — there is little future for coal in this country.

CCC have pointed out that Britain's miners have worked to build an industry that has doubled its output per man shift since 1985, and now sell its product to the generators at 30% less in real terms than its 1985 price.

In order to facilitate a moratorium, CCC believes the Government should curtail the use of imported coal in power stations, under the terms of the ECSC Treaty. In addition it should stop the issue of licences for further gas-fired power stations, and ban the use of orimulsion in stations not fitted with FGD equipment, using powers under the 1990 Environmental Protection Act. The CCC also believes that gas-fired plant already with licences should be required to prove that they can produce electricity more cheaply than the existing coal-fired plant they replace.

Boost for Ballymoney lignite

FOLLOWING the sale of Northern Ireland's four power stations, British Gas, who purchased the Ballylumford oil-fired station near Belfast have committed themselves to bringing gas to Ulster.

The move has been welcomed by Meekatharra Minerals, whose Ballymoney lignite project looks likely to gain from such competition. British Gas has advised

Ulster's large energy users that non-interruptible gas supplies will cost them 30p per therm. Meekatharra claim that this is double the price of Ballymoney fuel on a heat equivalent basis. The company was further encouraged by both parties stating during the recent election campaign that they would restrict the future use of natural gas in base load power generation and also reduce coal imports.



ACE welcomes efficiency office move

THE Association for the Conservation of Energy (ACE) has welcomed the Energy Efficiency Office's move to the Department of the Environment, following the Conservative election victory.

Andrew Warren, Director of ACE, said: "We welcome the abolition of the Department of Energy and its stranglehold over energy conservation policy. That Department was always dominated by those concerned with the supply of energy, not with saving it."

Mr Warren took as positive evidence of a commitment to conservation and combating the greenhouse effect the Prime Minister's announcement that Britain will stabilise CO₂ emissions in 2000 rather than 2005. Pointing out that since 1990 CO₂ emissions have risen by 2%, Mr Warren commented: "The last few years have shown clearly that market forces alone cannot deliver the level of energy savings necessary ... it is time to introduce specific energy conservation programmes ... We have seen from other EC countries that such programmes deliver."

Extra cash for Scottish efficiency

AN additional £7.5 million is to be made available to 44 Scottish district councils for council house energy efficiency projects in 1992-3. The announcement was made in April by Lord James Douglas-Hamilton, Minister for Housing at the Scottish Office.

The Department invited bids from all Scottish housing authorities, and the approved schemes range from the establishment of shelter belts in the Western Isles to give protection to housing against prevailing winds, to the installation of boiler energy management systems and thermal insulation for bungalows in Falkirk.

Glasgow, Edinburgh, Dundee and Aberdeen have all been given extra allocations of between £0.4 million and £0.25 million. Extra allocations are expected to enable energy efficiency improvements on a total of 8,500 houses.

Concern on overcapacity

BRITISH COAL Chairman Neil Clarke expressed his concern about excessive expansion of generating capacity in his address to the Energy Industries Club lunch in May.

Adhering to the guiding principles of the privatisation process, business should have the right to expect a free market to trade in, said Mr Clarke. But imported coal at marginally costed prices as well as the heavy subsidies enjoyed by other European coal producers caused considerable market distortions. Even more worrying though was the recent National Grid report indicating that Britain was heading for 60% overcapacity in electricity generation by 1997. "I find it difficult to believe that 60% overcapacity represents a triumph for the free market," he commented.

Mr Clarke went on to point out

that the 'dash for gas' was largely responsible for this forecasted glut, with the result that despite a surplus, electricity would fail to become cheaper, as it must bear both the operating and capital costs of these new ventures. Even with FGD, he claimed, coal-fired stations retained their cost advantage.

He also emphasised that every gas-fired station licence approved closed another coal-fired station, along with another colliery or two. He concluded his address by saying "I don't believe British Coal has a divine right to supply fuel to the electricity industry. What concerns me is that BC, in striving to meet the demands of a market, will be a victim of a process that is taking advantage of, rather than optimising the change that is taking place in the electricity market."

Cooperation to ensure supply

A COOPERATION deal has been signed by Hydro-Electric and Eastern Electricity to cover emergency situations, such as major storms, when either company is experiencing serious disruption to electricity supply.

Both companies gain reassurance from the deal that extra skilled resources are available if needed to help restore electricity supplies to customers as soon as

possible.

● Hydro-Electric signed a contract with NORWEB in April giving the go-ahead for the construction of a 680 MW gas-fired combined cycle power station at Keadby, South Humberside. Due to come on stream in January 1995, 50% of the station's output will go to each company under a 15-year agreement.



The National Energy Foundation (NEF) announced in May that East Midlands Electricity are to be the first major sponsor of NEF's Odyssey project.

Odyssey — the National Energy Centre — will be located in the Milton Keynes Energy Park. The 12 000 m² complex will combine a business centre, with professional, commercial and educational facilities, and a public exhibition entitled 'the Energy Experience'.

Pictured above are John Harris, Chairman of East Midlands Electricity and Dr Mary Archer, Chairman of NEF.

MMC report on UKAEA

IN a written reply to a parliamentary question from Colne Valley MP, Graham Riddick, Corporate Affairs Minister Neil Hamilton has announced publication of the Monopolies and Mergers Commission report of the UK Atomic Energy Authority (UKAEA).

The Commission were asked to look into the UKAEA's efficiency and costs of service. They have concluded that although further improvements are possible, much is in the process of being achieved by the fundamental changes currently underway. The report identifies particular weaknesses in financial and project control, investment appraisal and marketing, and makes 58 recommendations for improving AEA's performance.

The report is available from HMSO price £19.40.

R&D centre in Scotland

USA MULTINATIONAL, FMC Corporation, is to set up a major engineering research and development operation at its Scottish plant in Fife.

The Chicago company, a world leader in the manufacture of high technology wellhead equipment for the oil and gas extraction industry, plans to invest £750,000 in a custom-built 10,000 sq ft addition to its existing operations at Pitreavie Business Park, Dunfermline. This prestigious expansion will create 29 new high quality jobs, and enhance the skills of around 60 engineering professionals.

The company's existing Scottish plant was opened in 1975 to manufacture and repair a full range of FMC surface and subsea wellhead products for customers throughout Europe, the Middle East and Africa.

The Dunfermline plant's successful focus on the expanding North Sea business over the past three years led to the decision to expand research and development activity in this area to complement its efforts at FMC Wellhead Equipment Division headquarters in Houston, Texas.



12 thousand miles Wright!

FOLLOWING the article on the 'Bulbsaver' (*Energy World*, November), a Fellow of both the UK and Australian Institute of Energy, Peter Browne, contacted HQ in Devonshire Street, expressing his interest in 'Bulbsaver'. We put him in touch with Microcel, the company set up by IoE Member Allan Wright to market his invention.

As a result, documents were exchanged, and a new company Uston Pty Ltd was set up and given sole agency for distribution. Samples of 'Bulbsaver' were submitted to SECWA (State Energy Commission of Western Australia) for testing.

After extensive testing and examination 'Bulbsaver' was accredited for connection to SECWA electricity supply. Uston immediately ordered 100 'Bulbsavers'.

Further interest has been expressed by The Netherlands and 100 'Bulbsavers' have been sent to Holland for trials.

British Rail are currently testing Mr Wright's invention, with a view to reducing the frequency of changing signal bulbs, an operation which can cost up to £50 a time.

LEMS Revisited

THE 1990 Cranfield/Esso seminars on this topic, directed principally to school staff and governors, were briefly reported in the April 1992 edition of *Energy World*.

Headteachers and governors who are unable to attend these excellent seminars in their areas, may wish to contact the Enquiries Bureau, BRECSU, Building Research Establishment, Garston, Watford WD2 7JR, and ask for Best Practice Programme Guides (ex Energy Efficiency Office) Nos. 15, 16, 17, 29, 39, 41, and BRECSU leaflets 13, 22, all relating to reducing energy costs at school. Anyone wishing for an extended report on the Esso/Cranfield 1990 series, which fully gives the flavour of these meetings, may write to Dr P J Padley, Chemical Engineering Department, University College of Swansea, Swansea SA2 8PP enclosing SAE, A4 size, please.

A warm welcome for our new President



New President, Michael Roberts (above); and left, a warm handshake from Past President Robert Evans CBE, at the Institute's Annual General Meeting in May.

Obituary

Dr Gordon Whittingham

GORDON WHITTINGHAM, Fellow of the Institute of Chemistry, and a former President of the Institute, died on April 6 1992 after a long period of illness.

After a brilliant academic record at The Herbert Strutt Grammar School, Belper, Derbyshire, Dr Whittingham studied Natural Sciences — Friction and Surface Films at Caius College, Cambridge, with Professor Norrish and here he obtained his PhD.

He began his career in Fuel Technology in 1942 at The British Coal Utilisation Research Association BCURA where he formed a strong team to study deposition and corrosion problems associated with the combustion of coal. Much of the research work was sponsored by the Boiler Availability Committee who, at that time, were studying severe problems of boiler fouling and corrosion with power station boilers fired with mechanical stokers. The work of Gordon's team on low temperature corrosion problems associated with economisers and air preheaters complimented that of Dr Crossley of the Fuel Research Station on high temperature corrosion problems associated with superheaters.

As a basis for this study, his team at BCURA developed the dewpoint-meter and corrosion probe and introduced theories on the mode of formation of sulphur

trioxide in the flue gases and on the relationship between the sulphur trioxide content of the flue gases and the variation with temperature of the corrosion of metal surfaces in contact with the gases. This work has formed the basis of many papers produced by his team and of subsequent investigations by many scientists of these problems with both coal-fired and oil-fired plant.

In later years, he frequently recalled the happy days that he spent at BCURA, both on and off the cricket field, with his laboratory colleagues, many of whom reached the top of their professions in later years in various branches of fuel technology. During this period he developed a close relationship with scientists at Battelle, Columbus, USA which he continued throughout the rest of his career.

He joined Technical Services Branch in British Petroleum plc in 1956 and continued with the application of research work to solving the problems associated with light and heavy fuel oils. Here, his gentle persuasive manner won him many friends at BP Research Centre, Sunbury and in BP Companies and academic bodies in Europe, Australia and North America. His world-wide reputation was respected throughout the organisation and further new successful developments by the TSB team and BP Research followed. Mobile laboratories were intro-

duced here and abroad to further the application of research to technical and pollution problems.

Ever since his early days with BCURA he took a great interest in the expansion of the Institute of Fuel, later the Institute of Energy. Most of his papers were published in the Journal. His enthusiasm for the Institute and close and friendly cooperation with so many active members resulted in his election to be President in 1973-74. During his period of office, the important conference, Fuel and the Environment, was held in the Congress Theatre, Eastbourne. H.R.H. The Duke of Edinburgh gave the opening address and contributions were made from leading figures in all branches of fuel technology. Twenty years later, many of the programmes initiated at this Conference are being applied.

Despite an initially full and active retirement, he progressively suffered from ill-health but his mind was still very lively and he was always open for consultation and discussion.

Diana, his wife, also from Derbyshire, was always a great support for him during his days at BCURA and BP, during his period of office at the Institute and, particularly, during the later sad months. Our thoughts go out to her and to his caring son, Andrew, and family.

Byrom Lees

Next edition

The next issue of *Energy World* is a combined July/August edition and will appear in August.



METHANE is a colourless, odourless gas which when mixed with air forms a mixture colloquially known as fire-damp. It is a hydrocarbon ordinarily the principal constituent of natural gas and forms 40% of all gas released from coal. It has always been a hazard to miners, as firedamp can easily be ignited and its partial combustion gives rise to carbon monoxide. For safety reasons therefore it has always been essential that firedamp be removed from active coal mines to the greatest extent possible. Originally the gas inside the mine was exploded as it accumulated. This practice was hazardous and interrupted production, and so during the 19th century a technique of draining the gas through service vents was developed.

Coal bed methane was perceived as a dirty gas and a pollutant. Nevertheless it was readily released into the atmosphere or burned at the point of exit to the surface. Modern technology enables coal bed methane to be upgraded to meet end use specifications for both industrial and, to a certain extent, domestic use, due to its often low sulphur content and relative purity. To process the gas for commercial use it may be pressurised, for movement in high pressure pipelines, and small amounts of propane may be added to increase its calorific value.

As early as the first half of the 18th century some people could see commercial potential for methane. Mr Carlisle Spedding, Manager of the Whitehaven collieries, offered to supply the harbour at Whitehaven with sufficient gas to light the town. His offer was refused, but Dr Brownrigg, a scientist living in Whitehaven, was supplied with gas through a lead pipe to his laboratory from an adjacent pit.¹ Only recently has Mr Spedding's example become accepted as an economically and commercially beneficial resource. New processes for the exploitation of methane through coal bed methane wells seek not only to use the gas as it is released from the coal seams, but to go further and stimulate the release of gas.

Methane from mines

Since 1957 licences for methane drainage have been issued in accordance with regulations made under the Petroleum (Production) Act 1934, the most recent being the Petroleum (Production) Regulations 1982.² Applications are made to the Minister for Energy.

The licence confers a right to get natural gas in the course of operations for making and keeping safe mines whether or not disused,

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Exploitation of coal bed methane

by Scott Barraclough*

In the past coal bed methane has been largely overlooked, being perceived as unwanted, and potentially highly dangerous. But the recent recognition that it is one of the most potent of the greenhouse gases has forced the international mining industry to look again at the subject of methane. Scott Barraclough recounts the history of coal bed methane and reflects on its future potential.

within an area specified on a plan, in consideration for the payment of a fee to the Minister. The licence runs for a period of 25 years and may be determined on one month's written notice from the licensee.

In a traditional mining operation, as caverns are created the methane and other gases 'desorb' (escape) from the cleats and micropores of the coal (and to a lesser extent the surrounding rock) into the underground workings from where they are drained with the ventilation air and lost into the atmosphere. In an active mine, 40–50% of the available coal is left in place after active mining operations are concluded. The mined out area will be closed off, and sealed in order to eliminate continuing methane seepage into the atmosphere or other current working areas of the mine. Any coal remaining will continue to release methane into the sealed cavern.

Operations to remove methane from abandoned collieries can be maintained under certain conditions. The mine must be dry and have sufficient reserves of gas-producing coal, with a tight seal but allowing the controlled passage of gas through a shaft. Methane extracted from gas drainage wells suitable for economic exploitation generally accounts for only about 10% of the total extracted gas, but in a successful degasification system methane could account for more than 80% of the gas drainage. A geological survey of the Waterschei colliery in Belgium showed that a pipe left in place in one of the shafts started to blow air immediately after the sealing of the mine with a methane content which increased from 50% after two weeks to 82% after six months. The pipe was eventually shut off in October 1990, a little over two years after the mine was abandoned. It was calculated that during this period approximately 5.5 million cubic metres of methane per year had escaped.³

Methane will also exist in unmined raw coal seams. Within such coal seams the methane gas is sealed underground. This reduces the

amount of gas naturally venting into the atmosphere, but the dense permeability of these untouched seams minimises the amount of gas which can accumulate in any given spot.

Consideration was nevertheless given to projects in which it was proposed that wells be drilled into the coal seam and the coal 'fractured' to release the gas. The first such coal bed methane well was sunk in the San Juan basin in New Mexico in 1977. Today projects are underway not only in the USA but also in France, Belgium, the United Kingdom, Poland and Australia.

Extracting methane

Before a proposal can be made as to the most effective way to develop coal bed methane, detailed geological, mining, marketing cost, drilling and engineering data must be analysed and ownership and regulatory requirements considered. Each step of the way in methane production can be critical. In extreme cases where the coal seam has not been mined the difference between a producing methane well and a non-producing methane well can be a variation of only a few metres in deciding on the well site, this makes initial production expensive.

Most producing wells will require some type of stimulation to increase the production rate to an economic level. Stimulation usually takes the form of hydraulic fracturing, and such treatments have now been successfully applied to thousands of wells around the world. The placement of a conductive fracture into a coal bed is far more complex than into other gas bearing rocks, but if properly implemented, fracture treatments employing state of the art techniques, procedures and chemistry, will successfully stimulate methane production by placing a fracture in the seam which allows numerous cleat systems in the coal to gain access to the bore hole or shaft. The increase in



methane production following a fracture stimulation treatment should directly correspond to the cleat systems in contact with the induced fracture. Fracturing treatment is expensive due to the characteristics of coal which require each fracture to be virtually custom designed.

Further problems may be experienced with high water production immediately following hydraulic fracture stimulation. Removing the water from the mine, and more importantly from the gas (often referred to as de-watering) is a significant problem in large numbers of methane wells in the United States. A significant capital outlay is often necessary to install water disposal systems. This together with the fact that questions remain over the ability to mine a seam after fracturing may make such projects unsuitable for many coal seams.

Storing coal bed methane

Obtaining methane from a worked coal seam gives the gas a unique storage capability. Methane which has been produced from the mine may be transferred in a pipe to above-ground storage facilities, alternatively the underground void acts as a natural storage area accumulating methane (and some other gases). If the mine is sealed this gas will build up to a static level causing the desorption process to stop. The major advantage of gas storage in a coal deposit is that the volume of storage gas can be increased ten fold compared to the available open space because of the adsorption capacity of the coal. In Belgium two closed collieries have been transformed into gas storage plants.

Before methane can be stored in this way three factors must be considered:

- all old and sometimes long disused shafts to the mine must be sealed, this is an unforeseeable cost factor in commencing a storage project;
- the gas adsorption capacity of the coal is of vital importance for the viability of such a project, and requires detailed investigation;
- the gas could migrate to more permeable or fractured areas above the storage chamber, eventually making its way to the surface and the atmosphere. If the methane is able to migrate to the surface, there is a risk of fire and potential for other environmental damage.

The words 'expensive', 'uneconomic' and 'significant capital outlay' have been used above but what makes coal bed methane extraction so cost intensive?

There are five major differences between coal bed methane development and conventional natural gas development:

- most coal bed methane development projects will have a large number of wells in comparison to other gas developments, this is due to the low porosity of coal in relation to other forms of rock which means that there is only a small amount of free gas present;
- there will be lower reserves of gas in coal bed methane wells;

- due to the above points the capital costs per well will be lower, but the capital costs per cubic metre will be higher;
- the billed operating costs for coal bed methane will be higher, due mainly to the necessity to remove the large volumes of water produced, to compress the gas into a form which can be handled by the high pressure pipe lines and the large numbers of low productivity wells;
- it is not uncommon for a well to produce for several months or even years before peak production is reached, this is at a time when costs are high, and if production is not maintained water will seep into the coal and the dewatering process must be re-started.

Gas exploration is a risky enterprise, and although banks may lend money for conventional gas development with good projections, coal bed methane is still an unusual fuel source and few financial organisations will be prepared to finance exploration projects. In spite of this over 2% of the gas sold in the United States today is from coal bed methane, most of the risk having been borne by large exploration companies who have been assisted by the government with low royalty and tax rates. This special tax credit helped to stimulate coal bed methane

production by encouraging investment to over \$3 billion, which has been used to boost US methane production from zero to 28.2 million cubic metres per day in the last decade and has encouraged 6,000 wells to be drilled. The number of wells is expected to increase by 50% during the current year and the proportion of gas sold is expected to at least double, however this will be an artificial growth fuelled by the withdrawal of the tax incentive at the end of 1992.

Development areas are more easily identifiable where mining exists or has existed, of course. If reserves of coal bed methane are sufficiently large, production from such sources will cost less to drill and develop than conventional gas prospects.

In many countries coal bed methane development is becoming a new industry, producing new jobs and new energy sources. An immediate advantage in developing coal bed methane from active mines is the reduction in mining costs by providing a self produced energy source for use in mining operations, or methane drainage for safety may even produce a sufficient quantity of gas to form an extremely lucrative by-product.

Environmental concerns

Coal bed methane is a major contributor towards the greenhouse effect when allowed to escape into the atmosphere. Methane emissions are greatest from vent holes in the sealed areas of active mines, from mines which are active and from inactive mines. Therefore, if coal bed methane is pumped out of these places to be commercially developed, it will no longer escape into the atmosphere in its natural harmful form.

No statistical data is available on the rate of global methane emissions, but it is estimated that a mine containing gassy seams could vent between 20 and 60 million cubic metres of methane per annum.

There are, however, two points for concern when methane is commercially exploited:

- the large quantities of water pumped from the coal and the gas during de-watering contain chlorides which without care could filter into drinking, and other fresh water;
- carbon dioxide is produced when the gas is burned. Carbon dioxide is the most prevalent of the greenhouse gases and its emission is carefully regulated in most countries. In the UK the release of any oxide of carbon into the air is regulated by Section 2 of the Environmental Protection Act 1990.⁴ It should be mentioned that although carbon dioxide is the most prevalent greenhouse gas, methane is considered by the International Panel on Climate Change (IPCC) to be more potent. The IPCC calculated that an emission of 1kg of methane into the atmosphere has 63 times the global warming effect than the emission of 1kg of carbon dioxide.⁵ If this analysis is correct the environment could be better served by burning methane.

Historically, methane has been overlooked as an unwanted and dangerous incidental mineral

The author



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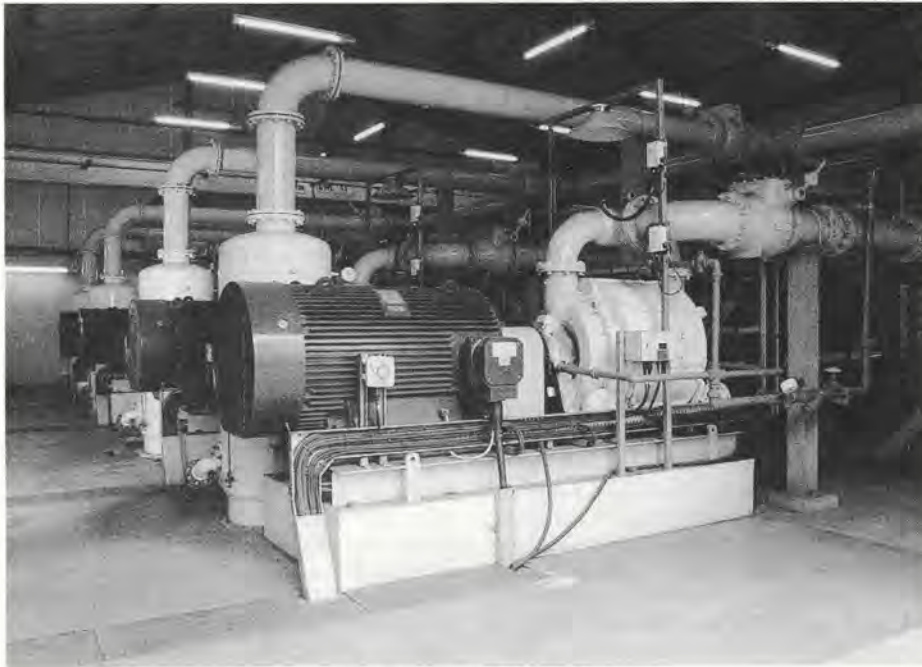


Photo courtesy of British Coal.

associated with the production of coal. It has been found to contribute to global warming when left vented to the atmosphere. Today it has potential advantages not envisaged in earlier times. It is a new source of relatively clean-burning energy which is found on virtually all continents. Methane also has the potential to reduce national imports of gas in countries such as Belgium and Poland, which improves their energy security, as well as reducing methane emissions to the air. Such development will inevitably have other knock-on economic benefits, such as increased employment and economic growth. □

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- 1 Slade J in Earl of Lonsdale v Attorney General (1982).
- 2 SI No 1000 of 1982.
- 3 Contained in a report prepared by M Duser and P Verkoren in March 1992.
- 4 By virtue of Regulations 3(1) and 6(1) of the Environmental Protection (Prescribed Processes and Substances) Regulations 1991 (SI No 472 of 1991).
- 5 Quoted from 'Coal Bed Methane in the UK' by Catherine Mitchell, *Energy Policy*, November 1991, p 849.

Methane extraction plant at British Coal's Harworth Colliery in Nottinghamshire.

Energy, Transport & the Environment Seminar

The New Connaught Rooms, London - 25 November 1992

9.15	Welcome Address & Introduction	2.20	The Case for Alternatives
9.30	Demand for Transport in Greater Europe	2.40	Discussion
10.15	Impact of Environmental Constraints	2.55	Future Technology for Road & Air Transport
11.00	Morning Coffee	3.15	Afternoon Tea
11.30	Determining Future Energy Requirements	3.35	Future Technology for Rail Transport
12.15	Panel Discussion	3.55	Discussion
12.45	Luncheon	4.10	Policies to Reconcile Economical Issues
2.00	Challenges for Traditional Fuels	4.30	Discussion
		4.45	Conference Summary
		5.00	End of Conference

For further details, please contact:

The Institute of Energy, Conferences Department, 18 Devonshire Street, London, W1N 2AU
Tel: 071-580 0008 Fax: 071-580 4420



Fuel Cell Technology — into the 90's

THE need for and the continuing promise of solid oxide fuel cell (SOFC) technology has developed more rapidly than expected a few years ago. The Westinghouse Electric Corporation, reacting to this favourable progress, maintains and funds, in cooperation with the US Department of Energy (DOE), other agencies, and domestic and foreign utilities, multi-million dollar SOFC development programmes. The objective of these programmes is to commercialise the SOFC technology during the 1990's.

The tubular SOFC is an electric power generation technology which can cleanly and efficiently utilise our fossil fuel supplies. The SOFC technology is in the preliminary design stage of development with plans for field testing of multi-hundred kilowatt and multi-megawatt rated generators during the early to mid 1990's. The SOFC technology operates efficiently at atmospheric pressure at 1000°C and thus has the potential for integral reforming of natural gas and direct utilisation of coal derived fuel gas.

The economic market potential for the SOFC technology extends from small commercial and small industrial applications to large multi-megawatt plants for large industrial cogeneration and all-electric applications. In addition, the SOFC technology offers significant user benefits which include: (a) electrical efficiency greater than 50%; (b) virtually unlimited plant site selection as a result of low emissions and make-up water requirements; (c) factory manufactured modular packages which reduce plant lead time, minimise site erection costs, permit high levels of quality control, and enhance user planning flexibility to better match load growth and minimise capital exposure; and (d) enhanced versatility through fuel adaptability and waste heat recoverability, permitting either baseload or intermediate load all-electric power plant operation or cogeneration plant operation.

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by *W J Dollard** and *W G Parker***

Solid oxide fuel cell (SOFC) technology has developed rapidly over the last few years. As an efficient and clean technology within electric power generation, its use is highly important in the ever widening field of multi-million dollar technological programmes.

A number of significant SOFC programme milestones have been realised during the past several years:

- Scaleup of manufacturing capability was demonstrated in the construction and operation of a 28,000 sq ft pre-pilot manufacturing facility (PPMF) dedicated to the production of SOFC cells and systems.
- Scaleup from 30 cm long cells used in the research phase of the programme was demonstrated with the successful production of cells with active lengths of 36, 50 and 78 cm.
- Improved cell voltage stability (<2% per 1000 h degradation rate) and life (greater than 20,000 h) were realised in the continuing development programme.
- Direct fuelling with natural gas was demonstrated in the operation of a 3 kW SOFC module for more than 5000 h and a 20 kW SOFC module for more than 1700 h.
- Extremely high availability (>98%), low pollutants emission (<2 ppm NO_x) and noise level (<60 dB) characteristics were demonstrated in the 3 kW SOFC systems operated by the Tokyo Gas Company and the Osaka Gas Company.
- Suitability of the basic module design for scaleup was confirmed in testing of 3 kW modules, in detailed design and testing of a 20 kW module, and in conceptual design and engineering evaluation of multi-hundred kW and multi-MW modules.
- Competitive system performance and cost potentials were confirmed in application studies of 50 to 2000 kW natural gas fuelled cogeneration units and 25 kW coal gas fuelled central station plants.
- Next phase of the commercialisation programme is underway — 25 kW SOFC systems are currently being fabricated. The first unit, which produces dc electric power, was delivered in 1991 to The UTILITIES, a consortium of the Kansai Electric Power Company, the Tokyo Gas Company, and the Osaka Gas Company. The second unit, a cogeneration system

producing both ac electric power and intermediate pressure steam, was delivered to the Joint Gas Utilities, a consortium of Tokyo Gas Company and Osaka Gas Company.

A more detailed description of these significant milestones is included in the sections that follow.

Solid oxide fuel cells are highly efficient electrochemical devices that can operate at atmospheric or elevated pressures and at temperatures in excess of 1000°C to produce electricity from fossil fuels such as coal derived fuel gas, natural gas, or distillate fuel. The temperature of the exhaust gases from the cells is between 500 to 900°C — a temperature which is attractive for cogeneration applications or for use in bottoming cycles for all-electric central station power plants.

The SOFC cells readily conduct oxygen ions from an air electrode (cathode), where they are formed, through a solid electrolyte to a fuel electrode (anode), where they react with carbon monoxide (CO) and hydrogen (H₂) contained in the fuel gas to deliver electrons and produce electricity. The state-of-the-art tubular SOFC (Figure 1) developed by Westinghouse features a porous air electrode made of strontium-doped lanthanum manganite that is overlaid onto a porous, calcia-stabilised zirconia support tube. A gas-tight electrolyte of yttria-stabilised zirconia (approximately 50 microns thick) covers the air electrode, except in an area about 9 mm wide along the entire active cell length. This strip of exposed air electrode is covered by a thin, dense, gas tight layer of magnesium-doped lanthanum chromite. This layer, termed the cell interconnection, serves as the electric contacting area to an adjacent cell or to a power contact. The fuel electrode is a nickel-zirconia cermet and covers the electrolyte surface except in the vicinity of the interconnection.

For operation, air is introduced to the fuel cell through an air injector tube. The air, discharged from the injector tube near the closed end of the cell, flows through the annular



space formed by the cell and the coaxial injector tube. Fuel flows on the outside of the cell. Typically, 85% of the fuel is electrochemically utilised (reacted) in the active fuel cell section. At the open end of the cell, the remaining fuel is combusted using the oxygen depleted air stream exiting the cell.

To construct an electric generator, individual cells are "bundled" into an array of series-parallel electrically connected cells forming a semi-rigid structure that is a basic generator building block. The individual bundles are arrayed in series to build generator voltage and to form submodules. The parallel electrical connection to the cells within a bundle enhances generator reliability. Submodules are further combined in either parallel or series connections to form the generator module.

The adequacy of the basic module design has been demonstrated by the operation of 12 generators, including those operated under field test conditions by the Tokyo Gas Company and the Osaka Gas Company. Engineering studies confirm that scaleup to multi-hundred kW and multi-MW commercial modules is practical. Individual modules would produce, for example, 200 kW electric for on-site cogeneration applications and typically 2 to 4 MW electric as the basic building block for large coal gasification or natural gas fuelled central station power plants.

The development of the SOFC technology was intensified in 1980 under a joint programme between DOE and Westinghouse. This ongoing programme is focused on continuing to develop, improve, and scale up the tubular SOFC technology for use with coal-derived fuels. The most recent accomplishment of this programme was the successful operation of a 20 kW SOFC generator directly on pipeline natural gas. The primary objective of the present programme is the design, fabrication, and testing of multi-hundred kilowatt SOFC generators and multi-megawatt SOFC generators both at Westinghouse and at customer sites.

The successful commercialisation of the SOFC technology during the 1990's depends on the ability to produce cost competitive systems that can operate for five to ten years before replacement of the SOFC module(s). A thorough understanding of the phenomena that limit cell and generator lifetime is required in order that new processes and/or materials, as may be needed, can be developed. Furthermore, a detailed understanding of the manufacturing cost of cells and generators is also required in order that more cost effective processes and procedures can be implemented.

Our goal is to develop a cell that can operate for 50,000 to 100,000 h with a voltage degradation rate much less than 1% per 1000 h. During 1990, a cell surpassed 20,000 h of operation with a voltage degradation rate of 1.4% per 1000 h. This cell, of course, was the longest running SOFC in the world — it was intentionally shut down for detailed examination (the cell could have operated longer) in order that improvements can be made in future cells. Eight more advanced cells are presently under test for more than two years with degradation rates ranging from 0.5% to 1.5% per 1000 h.

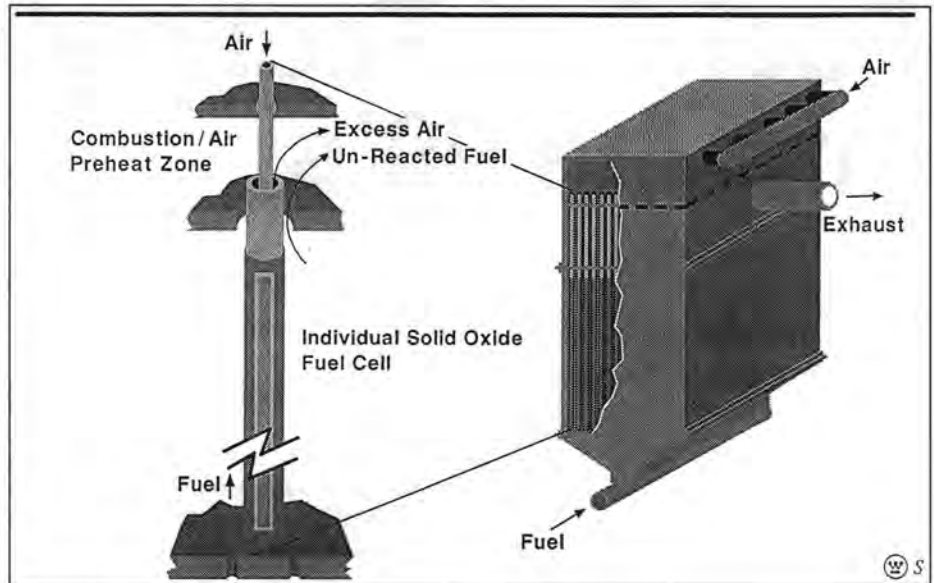


Fig 1: SOFC cell and module.



The Westinghouse pre-pilot manufacturing facility.

Engineering studies indicate that the current cell cross-section (approximately 0.5 in diameter) is satisfactory for commercial use but that cell length and power density need to be increased. Longer, higher power density cells will make an important contribution to practical and cost effective commercial systems. The majority of the cells utilised in the research phase of the programme through 1986 were 30 cm in length; 36 cm long cells were demonstrated in the Tokyo Gas Company and Osaka Gas Company 3 kW SOFC units operated in 1987/1988.

A major step in the commercialisation programme was construction of the 28,000 sq ft PPMF. This facility is located near Pittsburgh and is dedicated to the SOFC technology. The PPMF provides the opportunity to move the technology from a laboratory environment to a manufacturing environment, and enables the processes and quality control programmes to be put in place that will be

required to commercialise the technology during the 1990's. All equipment for the production and quality control of multi-hundred kilowatt SOFC modules containing 1 m long cells is in place.

Bundle Test Four (BT-4), the first SOFC test article fabricated at the PPMF, consists of two bundles of 18 50 cm long cells. This test article was fabricated during 1989 and was designed to demonstrate that the transfer of technology from the laboratory to the PPMF had been successfully accomplished. BT-4 has completed over 6800 h of stable operation at 1000°C with eight planned thermal cycles (from room temperature to 1000°C and return to room temperature) for a total test period of over 8000 h. The successful thermal cycling tests indicate that the SOFC technology has the potential for numerous start-ups and shut-downs similar to more conventional power generation equipment.



A major milestone of the SOFC programme was the fabrication of the multi-kilowatt generator (MKG) (Figure 3). The MKG, rated at 20 kW, contains five hundred and seventy-six 50 cm long cells. The MKG was successfully started in November 1990 and has operated more than 1700 h on pipeline natural gas. The design, fabrication, and testing of the MKG was a primary objective of the past phase of the development contract with DOE.

Cells of 1 m length were investigated at the PPMF during 1991. Our engineering studies indicate that this cell length can satisfy the commercial cogeneration market requirements of the 1990's and beyond. Future manufacturing programmes will address still longer cells, which will further improve the economics for large central station electric utility power plants.

The ability of the SOFC generator to operate on pipeline natural gas was demonstrated in the 1988/1989 time frame with single cell testing, bundle testing, and testing of a 3 kW SOFC generator as part of a contract funded by the Gas Research Institute (GRI). The 3 kW SOFC generator was operated for more than 5000 hours on pipeline natural gas. This development is being continued with the initiation of the design of the 100 kW SOFC generator for DOE. This generator will ultimately be part of a 100 kW SOFC system planned for operation at a customer's site.



20 kW SOFC module.

Two SOFC systems, each rated at 3 kW, were delivered and installed in November 1987 at facilities of the Tokyo Gas Company and the Osaka Gas Company. The 3 kW systems were tested at Westinghouse for a total of 400 h prior to shipment to Japan. The Tokyo Gas Company system was operated continuously for 4900 h. Ease of maintenance (module replacement) was demonstrated on the Osaka Gas Company system. The gas companies reported (1988 Fuel Cell Seminar) that the units met specifications with availabilities greater than 98%, showed over 50% efficiency,

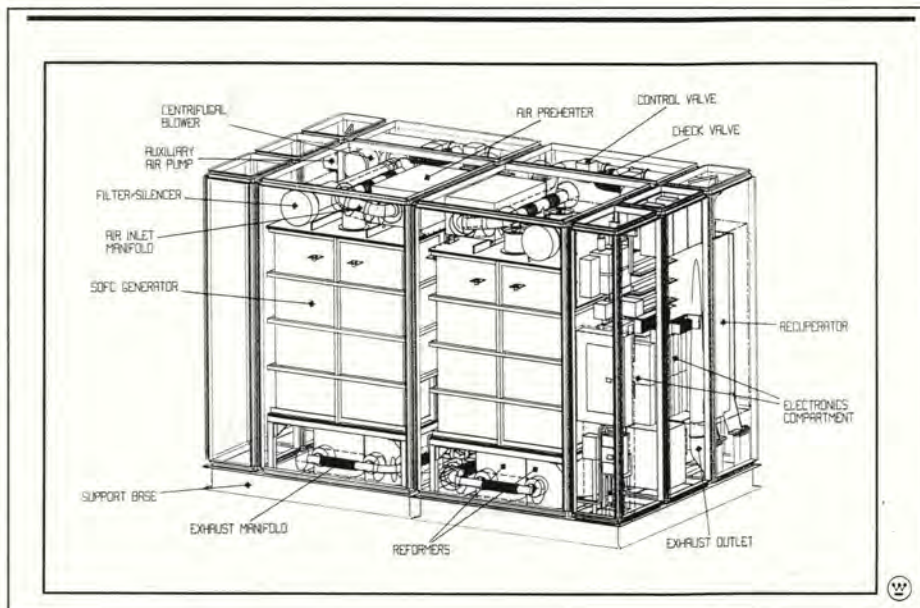


Fig 2: 25 kW SOFC field unit.

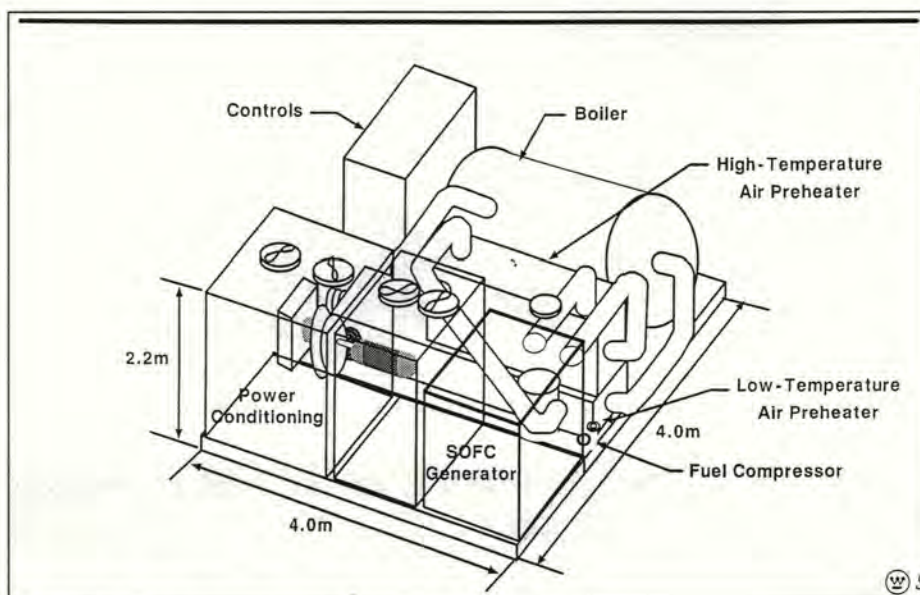


Fig 3: 200 kW SOFC cogeneration system baseline design.

and substantiated the expected low environmental impact of SOFC systems (measured values of 1.3 ppm of NO_x at 18% O_2 , 55 dB at 4 m).

Twenty-five kW SOFC systems (Figure 2) are currently being fabricated. The first unit, which will produce dc electric power, was delivered in 1991 to The UTILITIES, a consortium of the Kansai Electric Power Company, the Tokyo Gas Company, and the Osaka Gas Company. The second unit, a cogeneration system producing both ac electric power and intermediate pressure steam, was delivered to the Joint Gas Utilities, a consortium of Tokyo Gas Company and Osaka Gas Company. These units represent another order of magnitude scale-up in the SOFC technology committed to the field and they make use of the lessons learned in designing, manufacturing, and operating the MKG generator (20 kW) at the Westinghouse laboratories in Pittsburgh.

Application studies

The gas utilities' interest in the SOFC technology is primarily for on-site power generation for commercial and small industrial applications. The electric utilities have interest in using the SOFC technology not only for central station electric power generation but also for smaller dispersed generating plants located near the load centres. In some instances, the electric utilities have also expressed interest in using the SOFC technology or repowering existing units as well as for commercial and industrial cogeneration applications.

The GRI-sponsored programme was expanded to study applications and markets, and to develop conceptual designs and cost estimates for on-site cogeneration applications in the power range of 50 kW to 2 MW. This effort was sponsored by a consortium of gas utilities in Japan — Tokyo Gas, Osaka Gas,



Table 1: The Westinghouse Commercialisation Programme

Experimental Units		
25 kW	KEPCO/Tokyo Gas/Osaka Gas	1991
25 kW	Tokyo Gas/Osaka Gas	1992
Proof-of-Concept Units		
100–200 kW	3–5 units	1992/1994
1–2 MW	1–3 units	1994/1996–
Field Test Units		
On-site Market	100–200 kW	1994/1996
Utility Market	10–50 MW	Late-1990's

Toho Gas — in cooperation with the New Energy and Industrial Technology Development Organisation, with the funding being provided through GRI.

Figure 3 shows a typical configuration for a 200 kW SOFC cogeneration system. This unit produces 200 kW net electric power and 263 kg/h steam at 170°C for a cogeneration system efficiency (LHV) of 86%. The installed cost estimate is 1335 \$/kW net.

Studies of large (>20 MW) central station applications fuelled with gasified coal are part of the DOE programme.

Figure 4 shows the design of a 250 MW integrated coal gasification SOFC-steam turbine power plant. This figure shows the gasifier, two 30 MW SOFC “power blocks” (nine SOFC modules each), and the heat recovery steam generator that comprise one or two identical equipment strings. The predicted full load plant heat rate (HHV) is 7639 Btu/kWh. The installed capital cost of the plant is 1260 \$/kW, which compares favourably with integrated coal gasification combined cycle plants.

The evaluation of the SOFC technology for large central station or distributed power plant applications is also continuing as part of a cooperative programme managed by the Electric Power Research Institute and sponsored by the New Energy and Industrial Technology Development Organisation in Japan and five Japanese electric utilities — The Tohoku Electric Power Company, The Chubu Electric Power Company, The Kyushu Electric Power Company, and Electric Power Development Corporation. Two central station electric power plants (each rated at 300 MW) fuelled with coal derived fuel gas and liquefied natural gas (LNG), respectively, are being evaluated as well as a distributed plant rated at 20 MW and fuelled with LNG. These design studies should further establish the economic attractiveness of the SOFC technology for all-electric applications.

The Commercialisation Plan for the SOFC technology is summarised in Table 1. As previously discussed, 25 kW SOFC systems are scheduled for delivery in 1991/1992.

Future units planned will be in the multi-hundred kW size range. These proof-of-concept units are important since they will establish that Westinghouse has an SOFC technology that can serve high value, on-site cogeneration market applications, beginning in the mid-1990's time frame. The demonstration of a multi-megawatt size plant, which will be the forerunner to large central station electric power plants, is planned for the late-1990's. □

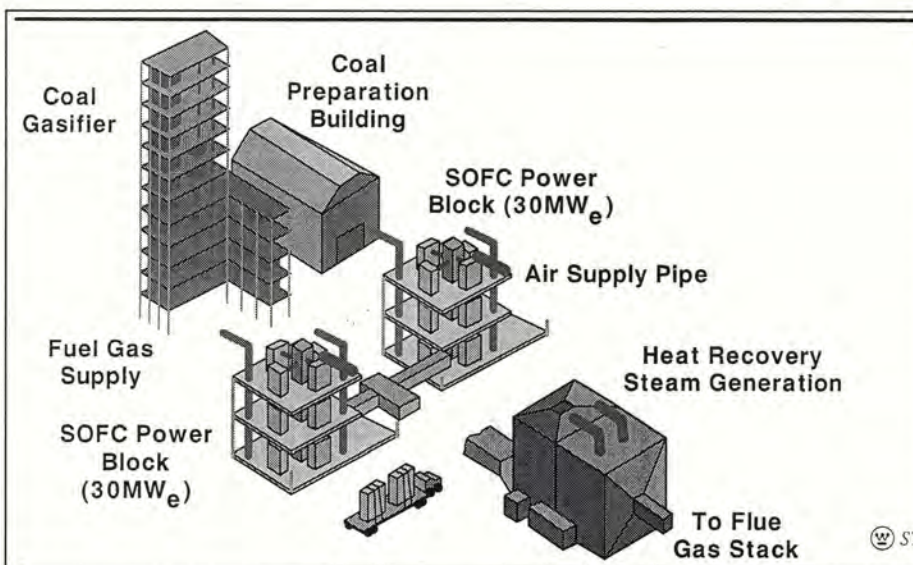


Fig 4: Integrated gasification, solid oxide fuel cell central station power plant.



Assembler unloads newly coated tubular cells from the electrochemical vapour machine at the Westinghouse Electric Corporation's solid-oxide fuel cell pre-pilot manufacturing facility.



Provision of the world's energy need

THE MODERN technological world requires energy. The present world requirement is probably approaching 10^{21} joules (J) per year, or a few times 10^{13} J/s (watts W) continuous. The energy is not distributed uniformly between people around the world: some 25% of the current world population in the developed world (perhaps 1.2×10^9 people) consume about 75% of the energy. This gives a mean energy usage per person there of about 7×10^3 W but the energy usage per person in the developing world is some ten times less. But these mean values hide the true variation: the range of the commercial energy usage for the year 1988 is shown in Table 1. The range is extremely wide and many people in the developing world still rely on traditional fuels (which are essentially wood and dried animal dung) for domestic fuel.

If all people in the world had the same mean requirement as the developed world, the current energy requirement would increase to as much as 5×10^{13} W: if each person had the same energy availability as the highest at present, the energy requirement would be ten times as much. The energy requirement of the developing world must surely grow and there must be the desire to reach at least the mean level of the developed world. The world population is continually increasing (it will probably be close to 6.5×10^9 people by the year 2000 if the present rate of growth continues) and the time for the population to double is itself decreasing.

The quantity of energy per second required by an individual to maintain life, without activity, is about 150 W, or 1.3 MJ per day: this

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In the following article Dr Cole analyses both the current and future world energy need, and looks at the contribution all the harnessable forms of energy could make to global requirements. Our future direction depends on moral and ethical questions, he argues, as technically most choices are feasible given time and money for R&D.

energy is contained in $\frac{1}{2}$ pint of petrol or in 2.5 pints of gin. This is a bad diet — the quantity of the energy alone is not sufficient but must be tempered by quality.

Most of the individual daily activities (such as walking or sleeping) can be undertaken using less than 500 W per person. In addition to the living requirement met by food, the necessary daily activity for the world population could be accomplished by a source of 2.5×10^{12} W, or about 20% of the present world energy requirement: the remaining 80% of the commercial energy we use supports the technological activities and various refinements of life that have become accepted as essential.

It is clear that there is here an energy spiral and that it is not determined by the basic energy requirement for life. Like all other attributes of the Earth, energy is a finite resource. What is the resource and how can the ability to provide energy be reconciled with the need for ever more of it? How can the desire compliment the need, and the need the reality?

The energy in the Universe appears in two separate forms. One (the rest energy) is locked into matter, being an alternative manifestation of matter itself. The situation is described by the theory of special relativity a mass m is the

manifestation of a localisation (or crystallisation) of energy $E_0 = mc^2$, where c ($= 2.99 \times 10^8$ m s^{-1}) is the speed of light in a vacuum. Matter as we perceive it is localised energy which is not available for use. To say that an object has a mass of 1 tonne ($= 1 \times 10^3$ kg) is to say that it represents the localisation of 8.94×10^{19} J. The freeing of any part of this energy, however small, causes the destruction of the mass and this energy is not generally available for use. The Universe that we can observe is composed, in gross terms, of some 10^{11} galaxies each with a mean mass of about 10^{43} kg, making the mass of the observable Universe about 10^{54} kg. The Universe can, therefore, be regarded as the manifestation of an energy of 10^{71} J, an unimaginably large quantity.

Matter (that is, crystallised energy) moves under the action of forces of various kinds and energy is associated with this movement: one form is the kinetic energy of motion, while a second is the potential energy of the position of an equilibrium due to the exact balance of forces (between large objects or between atoms). The forces themselves involve stored energy. The kinetic and potential energies, and sometimes the forces as well, can be made available to provide work transfer. These energies are infinitesimal in comparison with that frozen into matter itself.

The estimated future life of the Sun (and so of the Solar System) is of the order of 10^{10} years. Even a minute fraction of the 10^{71} J locked up in the matter of the Universe, if it could be made available, would satisfy all our energy needs for the indefinite future. Surely it must be possible to 'scratch' the Universe in some way and allow energy to 'drip' out. This is, in fact, not possible. The Universe has achieved a high

Table 1: Commercial energy usage per capita for different countries (1988)

Country	Ratio	Country	Ratio
Canada	1.0	Japan	0.40
United States	0.92	Italy	0.35
Saudi Arabia	0.78	Spain	0.25
Germany (E. Lande)	0.75	Mexico*	0.13
Sweden	0.69	Brazil*	0.15
Germany (W. Lande)	0.56	China*	0.08
USSR	0.54	Nigeria*	0.05
United Kingdom	0.44	India*	0.03

* Means supplemented by traditional fuels
[1.00 unit = 44.5 barrels of oil equivalent per year
1 barrel of oil = 6.4×10^9 J = 6.4×10^3 MJ]
(UN Statistics)

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stability against loss or rearrangement of energy and the rules controlling the energy are summarised in the laws of thermodynamics (literally the motion of heat).

The laws (of which there are three) deal with the magnitude and the quality of the energy. For the magnitude, they tell us that energy cannot be created or destroyed but only transformed from one sort to another — this is the so-called conservation of energy. For the quality, the emphasis is on order with complete disorder (randomness) having the lowest quality: the quality of an initial package of energy cannot be improved in a natural transfer process. Ideally the quality will remain unchanged but in practice, due to the action of friction, heat conduction and other irreversible effects, the quality is actually reduced.

Entropy

The quality of energy is often described by the term entropy (a composite word involving the Greek word for transformation), the greatest order having the lowest entropy. An equivalent specification involves the thermodynamic free energy, which is the energy free to be used to perform work. The free energy is greater the more ordered the system, that is the smaller the entropy. In broad terms it is found more natural to think in terms of entropy for general arguments about heat energy transfer but in terms of the free energy for the consequences of the specific transfer of energy (for instance in a chemical reaction).

Thermodynamics states that, for a system unaffected by the outside (called a closed system), the entropy cannot decrease in any transformation of energy — this is the content of the second law. Put another way, the quality of energy cannot improve: it will either remain unaffected by the transfer or it will disimprove meaning that the entropy will either remain unchanged or it will increase. A transfer of energy cannot occur if the quality of the energy would improve or if the free energy would need to increase. Thermodynamics in this way determines the direction in which a flow of energy can occur and can indicate the conditions under which such a flow will not occur naturally (it can, in fact, be made to occur if some external work is performed so increasing the entropy somewhere else).

There are many ways of expressing this situation giving an equivalent number of alternative ways of expressing the second law of thermodynamics. One statement of particular relevance now is that every working engine must have an active, hot exhaust pipe.

If heat energy is to be converted to work energy, some heat energy must be rejected and the quality of the initial energy must be reduced. The rejection of heat causes the warming of the environment and the lower quality of the rejected energy is a pollution. This is a vital result for energy provision: there will always be some environmental warming and pollution. The question then is whether the warming is large or small and whether the pollution is substantial and obnoxious.

There are nine general sources of energy available for the creation of work energy on Earth. All of them are associated with funda-

mental features of the Universe (a fact that is not often recognised) and each one is under the firm control of the laws of thermodynamics.

Energy from the Sun — Radiation from the Sun is abundant and of high quality, having closely the Planck distribution of frequencies for a temperature of about 5900K. The solar flux at the distance of the Earth (the solar constant) is about $1.4 \times 10^3 \text{W m}^{-2}$. The albedo of the Earth is 0.3 so that 30% of the radiation striking the Earth is reflected immediately back into space (to provide the Earth-shine the astronauts speak of): this leaves a mean energy flux of about 980W m^{-2} (say 1kW m^{-2}) entering the atmosphere. Of this amount, 80% (that is 784W m^{-2}) is absorbed by the Earth's surface (the continents and the oceans) and about 20% by the atmosphere. The free energy is raised by the absorption of this radiation (which doesn't actually heat the Earth but maintains a steady mean temperature of about 275K) and various processes are able to take place including photosynthesis (which involves about 0.06% of the incident solar radiation, or 0.6W m^{-2} spread over the surface).

These energies can be used to provide available energy for work transfer. Electrical energy is the most versatile form and it is convenient to consider the work production in terms of the production of electricity. The various possibilities are:

- the energy striking the surface can be collected and converted to electrical energy through some form of photovoltaic effect. This can be used directly or it can be used for breaking down water, and so provide a hydrogen based energy source;
- the incoming radiation can be focussed, through a mirror device, to heat a fluid directly, which could be water to form steam;
- the warm Earth environment emits infrared (heat) radiation, again closely of Planck form. If this can be contained in a volume (such as a house or a factory) the interior is warmed. Such passive heating of living space must play an ever increasing part in the living energy budget;
- the energy involved in photosynthesis can be made available by freezing the process (essentially killing the object undergoing photosynthesis) and breaking-up the constituent complex molecules to a chemically more simple form for use. This process is called generally the use of biomass. Energy is made available by the combustion of trees or of farmyard/household waste. The breakdown also occurs through natural decay of dead organic materials and the gases of decay (essentially methane and carbon dioxide) collected for use (through land fill). The burning of wood is still a major source of energy in the developing countries, although wood is becoming scarce in some regions of the world;
- fossil fuels are essential geological biomass. Trees and ferns that have died have been metamorphosed to form coal: ancient elementary sea creatures, collected in sedimentary deposits when they die, have been metamorphosed to form oil and natural gas (essentially methane) as part of the process of decay and rearrangement. The combus-

tion of coal and oil releases substantial quantities of energy frozen in the decay process and leaves a lower quality of material as pollution. The combustion of methane is different since there need be minimal pollution if the burning process is properly controlled;

- the energy absorbed by the rotating atmosphere causes winds, and wind energy can be harnessed to drive an electrical generator (or do other equivalent work) through some form of propeller system. This is the wind mill of earlier times but now given a more effective modern form;
- the action of wind on the surface of the seas and oceans produces waves and the energy of the sea (and particularly during a storm) is extremely large. The energy contained in a moderate North Sea wave is estimated at about 1kW per metre length. It is attractive to attempt to make this energy available for daily work transfer;
- precipitated water, trapped on high ground (from rain or melting snow), runs to the sea through turbine systems to provide electricity.

Tidal energy — The gravitational interaction between the Earth and the Moon (with a secondary contribution from the Sun) raises tides in each body. Those raised in the Earth's oceans can be the source of available energy through some form of estuary dam system located especially where the tidal effect is particularly magnified.

Geothermal energy — Considerable quantities of heat energy are given off by the solid Earth. Some comes from the deep interior and is a relic of the heat produced when the Earth was formed 4.6×10^9 years ago. The remainder arises from the decay of radioactive elements in the crust of the Earth.

Nuclear energy — This is the most basic form of energy yet available. It results from the rearrangement of the components of the nucleus of an atom and so involves a redistribution of the energy that was encapsulated when the nucleus was formed during a past supernova event. It is the only energy source that uses the expression of the special theory of relativity quoted in paragraph two and taps a source of energy used by nature throughout the Universe. There is the hope that the fusion of four hydrogen nuclei to form eventually one helium nucleus will provide practical energy on Earth. This is the source of the energy in stars (on a massive scale and highly controlled while the fuel lasts) and is alternatively the basis of the thermonuclear bomb (physically small but essentially uncontrolled once it is triggered). The problem of providing a highly controlled commercial variant of these two extremes has so far eluded researchers although work continues hoping for an ultimate solution.

Obtainable energy

The energy that can be extracted from these various sources for practical use is prescribed in various ways. Thus, the usefulness of the solar energy sources is largely determined by the area that can be used to collect it and by the Sun not shining at night, making a high density storage system essential. Hydrological energy is deter-



mined by the rain pattern and so the dynamics of the atmosphere. Tidal energy is determined by the strength of the gravitational interaction between the Earth and the Moon together with the topologies of the shallow waters near the shores. The geothermal energy is controlled by the properties of the Earth and particularly by the geology of the crust. The features of nuclear energy are determined by the strength of the interaction between the components of the atomic nucleus.

The density of the energy, that is the energy per kilogramme of the initial fuel source, is a crucial parameter since this determines the physical size of the power plant. In these terms the highest energy density by far is found in nuclear fuels, and the next highest in fossil fuels. The remaining sources are of low energy density by comparison.

A mean coal fuel provides 25.8MJ (1MJ=one million joules) per kilogram: a mean oil fuel provides closely twice as much energy while petroleum (derived from oil) provides rather less. Natural gas provides some 37.2MJ per cubic metre which is mid-way between the energy content of coal and oil. Artificial gas (for instance, coal gas) has an energy value of about 1/10th that of natural gas. Nuclear fuels have a higher energy density. 1kg of natural uranium in a thermal reactor provides the same energy as 4×10^4 kg of coal (about 1.2×10^{12} J) while in the more efficient fast neutron reactor (where all the uranium is used as fuel) this energy value is increased so that 1kg of uranium provides now 60×10^{12} J or the equivalent of 2×10^6 kg of coal. The advantages of the nuclear source from an energy point of view are obvious. The numbers of nuclear power plant in operation now and under construction in the world are listed in Table 2.

These energies can be made available in power plant of limited spatial size. The area of land used by a modern coal or oil fired power station is about 30 acres (134 hectares) employing perhaps 200 staff. A nuclear power station is if anything smaller. Petroleum energy sources can be small enough to be mobile (in motor cars or aeroplanes) although they then provide proportionately less energy. Electrical power can provide mobile power (for instance, in driving a railway system) although the widest flexibility of use will be possible only when a satisfactory high duty battery unit has been developed. Nuclear power sources can also be small enough to be mobile (for instance in submarines or in orbiting space vehicles). The energy density is high in all these cases, both in terms of the energy produced and in the smallness of the plant size. Such plant offer great flexibility in application.

None of the other power sources have all these advantages for gross energy production although each can have important local value. The conversion of solar energy to electrical energy is not a very efficient process at the present time (probably not greater than 10% overall) and the photovoltaic materials are costly to provide in time, energy and money. The world's weather, the curvature of the Earth and the Earth's rotation, distribution losses of the electricity produced, together with maintenance and repair losses of the associated equipment all reduce the efficiency further. In spite

Table 2: The numbers of nuclear power plant at present in use and under construction

Area	Number in use	Electricity generated (MWe)	Number under construction
Europe	184	1.265×10^5	31
North and Central America	129	1.112×10^5	11
South America	3	1.561×10^3	2
Asia	108	7.717×10^4	52
South Africa	2	1.842×10^3	0
Totals	426	3.183×10^5	96

(UN Atomic Energy Commission)

of these factors, the world's energy requirement could be met if some 10–15% of the surface of the Earth were to be covered by photovoltaic collectors. The proportion of the surface devoted to energy collection would grow as the world's population grew and so conflict with the increasing demand for living space by the growing population. (This can become a serious problem in the future: the world land area is about 1.49×10^{14} m² — including the Antarctic and the large mountain ranges — so the land area per person at the present time is about 3.2×10^4 m² (3.2 hectare=8 acre). By the turn of the century this space will have been reduced to 2.8 hectares (=6.8 acres) — traditionally one acre is the land necessary to grow food enough to sustain a family for one year.

National self-sufficiency using solar energy could be possible in the lower latitudes but the current energy requirements of European countries could hardly be met locally (either individually or collectively) even if all the land were under collection. High density energy storage (to take account of the night hours) would also need to be developed if this more local option were to be attempted. The technology for such an enterprise is in essence available but the social implications of what would need to be an international energy scheme may take some time to develop.

Biomass is less effective than active solar power collection. This source of energy has a higher conversion efficiency than photovoltaic devices but must contend with essentially the same losses in distribution. There is, in addition, the equilibrium time for a stable flora (about 10 years in general but 100 years for a rain forest). This approach could scarcely provide more than 10 or 20% of the present energy requirement even if all the land area were put under vegetation.

The atmosphere is a large energy reservoir and wind power has many attractions but its essential disadvantage is the weak interaction between the wind machine and the atmosphere for energy transfer. The interaction efficiency through a propeller system is intrinsically not high and the size of the machine must always be small in relation to the scale height of the lower atmosphere (about 8km).

Tidal and geothermal sources are constrained both in power and by location. Geothermal power may well become more important in the future if engineering techniques allow heat to be accumulated from the mid-ocean ridges which largely lie deep under the sea. The release of heat worldwide possibly approaches 10^{17} W.

The use of passive solar radiation presents a different picture. Theoretically, as much as 90% of the energy currently used for space heating could be saved by proper house and locality design and this option offers an exciting challenge for the architecture of the future. The development of appropriate new materials to support these efforts offer a challenge to the physicist and the chemist.

Global warming and pollution

Each of the methods of energy production provides environmental warming and each (with the exception of passive volume heating with an appropriate change of air through efficient heat exchanger) provides its own pollution.

The normal atmosphere introduces a basic warming due simply to its being there. The steady surface temperature of a planet is determined by the equilibrium balance of the received (high quality) solar radiation and (lower quality) radiation emitted by the surface. The equilibrium temperature T_e for the Earth neglecting the atmosphere is T_e (Earth)=256K, while the observed mean temperature, T_o , at the surface is about T_o =275K. This is a natural greenhouse effect which maintains the surface slightly above the melting temperature of water in the mean and this steady situation prevailed up to about the time of the Industrial Revolution. For Venus and Mars the corresponding temperatures are: T_e (Venus)=227K, T_o (Venus)=700K; T_e (Mars)=216K, T_o =220K. The important effects that the natural warming can have are clear.

The processes of energy provision lead to an enhanced warming while the energy provision takes place. This depends on two factors. One is a warming inherent in the conversion of heat energy into work energy and is the same for any source of fuel, the amount being determined by the universal laws of thermodynamics. The consequential temperature increment remains steady while the volume of energy production for work transfer remains unchanged. Some 10 times the present energy requirement of the world could be met continuously without raising the temperature of the environment by more than 1°C if only thermodynamic warming were involved. Such warming is not necessarily bad in principle: areas of the world now under permafrost could be freed for use if the ambient temperature were higher, though polar ice would also be melted and the sea level rise correspondingly — there can be a compromise here.



The second factor is an enhancement of warming that arises if the method of energy production interacts with the atmosphere or if there are changed conditions of the Earth's environment (such as a continually modified atmospheric composition). As one example, fossil fuels provide the warming dictated by thermodynamics but also a more important enhanced warming due to the emission of the greenhouse gases (and particularly carbon dioxide) produced in the combustion processes (this is part of the associated pollution). The proportion of CO₂ in the atmosphere has increased from about 280 parts per million by volume (ppm) in 1800 to about 350 ppm now. The burning of biomass will provide effects similar to burning coal although (because of the lower density of the fuel) a balance can be attempted then with the atmospheric carbon content: this will, of course, place restriction on the amount of combustion that could be allowed if environmental warming is an important factor. Nuclear power, on the other hand, gives no enhanced warming because no gases are emitted into the atmosphere and environmental warming then is the minimum required by the restrictions of thermodynamics.

Warming is not the only consideration — pollution must be included as well. Here the different energy sources fair differently. Fossil fuels are very pollutive, with the exception of natural gas which is composed primarily (some 97%) of methane which can be entirely burned cleanly with appropriate combustion. Carbon dioxide (a strong greenhouse gas) and sulphur dioxide (the prime producer of acid rain) are prominent products of coal and oil combustion. In addition a wide range of volatile and radioactive materials contained in the fuel are released into the atmosphere (a coal-fired station releases to the environment about three times the radioactivity of a nuclear power station). The intrinsic material pollution level here is very high.

The pollution associated with nuclear power is partly actual and partly potential. Radioactive waste is the actual pollution and, although the quantities are small and its disposal presents a purely technical problem, there is a psychological barrier which will need to be dispelled if nuclear power is to become a major world energy source. Actually, the waste represents the most concentrated source of rare-earth elements in the Universe (unless other civilisations in other galaxies exist and use nuclear power!) and these materials are of enormous value to modern technology — it could be that future generations will regard the deposited waste as an Alladin's cave! The potential pollution is the fear of nuclear accidents which pollute the environment. The problems of nuclear safety, already given a high priority in many countries (including our own) must be central in the list of visible solutions. This is one area that cannot be constrained by financial considerations alone if the nuclear power option were to be chosen. At the present time, nuclear fuels provide about 18% of the world's electricity which is about 4% of the total world energy budget.

The pollution (that is the resulting materials) associated with the actual production of the solar energy (essentially helium — the solar

wind is a pollution but is not worrying to us) are held in the Sun itself. This means that solar energy sources are not pollutive to the Earth in material terms. The pollution is non-material. A world full of solar radiation collectors, full of windmills, full of tidal barriers, full of forests being stripped and burned, or of energy devices at sea would present their own pollution to living. The efficiency of forest harvesting could perhaps be increased by the introduction of specially designed trees using genetic engineering — how will forests of unusual and man-designed trees, designed for their properties on destruction rather than their intrinsic value in a chain of living, appear in daily life? Will large areas of decaying biomass in discretely hidden land-fills satisfy our everyday aesthetic senses? Visual pollution can affect the quality of life as firmly as material pollution.

Time scale

It would be tempting to disregard these problems and continue in the well-worn ways for the time being, at least in some modified form. Unfortunately, this is neither possible nor ethical. Some 80% of the present energy requirement is met by fossil fuels and these have a limited future life quite separately from the pollution they provide. At the present rate of consumption, known oil and gas reserves will not last beyond 50 years from now (what happens to transportation then?), while coal has an expected usage of some 250 years left. Apart from the time scale, there remains the ethical question of whether it is right for this generation to deplete totally a natural resource (which is irreplaceable, at least with a time scale under many millions of years) rather than pass at least some of this valuable resource on to future generations.

Nuclear fuels using the thermal reactor system have an expected life no longer than that for coal: using the fast neutron reactor (and so using all the uranium fuel) the known uranium reserves will last for nearly 2000 years. Current fossil fuel usage must be replaced in the very near future by another primary source of energy provision, but the time scales for all high density sources (except the fast reactor) are small — some well within the life times of those being born today. It will certainly require several decades to design, manufacture and commission a new major energy industry and there is, therefore, no time to be lost in starting the enterprise.

What of the future?

The present energy problem, which in fact has the dimensions of a crisis, has come about for two reasons: one is the growing demand for energy and the other is the growing world population. The crisis has always been there inherently but it is the extrapolation of the earlier modes of energy production to extreme levels and the need to supply ever more people that now makes the problem critical.

Because the Earth represents a finite environment, the energy requirement must be held fixed at some level and at some time, now or in the future, and energy must be treated as the precious commodity that it is, both at home

and in the factory — there is not an indefinite supply of it. How we live and where we live are vitally affected by the scale of the energy provision. As an extension of these considerations it should be realised that more people requiring more manufactured articles will increase the need for raw materials as well as the energy to make them — there is also a finite mineral reservoir on the Earth. Design for the recycling of materials and the energy requirements of manufacture will each have an important part to play in future living. The individual freedom for using energy must be curbed, either by price or by consent, and in this process our way of life will be basically affected. A central requirement is the stabilisation of the size of the world's population.

It is not possible to use more energy than can be produced so there would seem to be two broad choices spanning those available:

- because the regeneratively produced energy provision cannot meet in practice the future growing global requirement, the regenerative energy sources must be supplemented and nuclear fuels appears the only possibility. The upper limit for energy production will then be determined by the limit of environmental warming that is internationally acceptable. This could provide up to 10¹⁵W for a 1°C rise in environmental temperature but will require a substantial international control of the associated nuclear technology;
- if the nuclear option is entirely rejected, the available energy will be prescribed by the regenerative energy that can be obtained supplemented in the shorter term by products (electricity or fuels) derived from coal through processes that do not pollute the atmosphere: the financial cost may well be high (cleaning the effluents from a fossil-fuelled power station will at least double the cost of the electricity produced). Energy saving and restriction must be a vital aspect of such a policy.

The nature of the dilemma which faces us becomes clear when we consider clean energy provision in the UK. The commercial energy requirement (see Table 1) is of the order of 1.3 × 10¹¹W. Renewable energy sources could collectively provide about 20% of this total, or about 3 × 10¹⁰W. The remainder (1 × 10¹¹W) is currently provided by fossil fuels. The general form of the proportional breakdown of the energy requirement is shown in Table 3. There is an obvious difficulty in meeting this requirement if fossil fuels are entirely excluded. The renewable energy sources could meet the residence and commercial energy requirements OR the transportation requirements OR a reduced industrial requirement but not all these together. The transportation requirement could be substantially reduced if public transport were more prominent — suppose here a possible saving of 50% of the total to 1.69 × 10¹⁰W; home and commercial heating could be cut substantially with better building design (there are about 20.5 million households to be made more energy efficient) and by wearing thicker clothing — the saving here could be as much as 90% or 9 × 10⁹W; the transmission requirement would be cut if power plant became smaller and more tailored



to local needs — suppose this is halved to 1×10^{10} W. The total reduced requirement is then about 3.6×10^{10} W. Regenerative energy sources could just provide this much energy, but industrial use has been completely ignored. One solution is to augment the reduced requirements by cleaned fossil fuel sources for industry, which could halve the present use of the fuel (to about 37%) but the financial cost of purification would be high and the increase would need to be passed on to the consumer. This does not overcome the limited known reserves although reduced usage would increase the life times to some extent. Another solution is the controlled use of nuclear power to provide the industrial deficit. There could be other solutions but none would avoid a substantial change of lifestyle. The present dedicated land usage may need to be changed (at present about 77% is agricultural and 9% forests) if regenerative systems were to play a large role in energy provision.

Holding the energy requirement to a prescribed level provides problems but possibilities. The development of automated industries in space would have the advantage of an increased energy budget without penalties of pollution or environmental warming on Earth. Sections of modern industry require one, other or all of the conditions readily obtainable in Earth orbit; a dust free environment; a very low temperature; a very high vacuum; a very low gravity. Perhaps the Moon will be developed eventually.

The practical maximum power outputs of the various energy sources at present available for large scale energy provision are summarised in Table 4. The estimates for regenerative sources are based on full world area coverage although in practice this must be an unattainable ideal.

It would appear unavoidable that changes in our attitude to energy provision, of a fundamental nature and involving questions of what is meant by the quality of life, await to be made now which will affect the way we live in the next century. These are essentially questions of ethics and morals; technically any choice can be met given time for the appropriate research and development. The changes must surely imply an increasing degree of international collaboration and involvement and a specifically European development would seem obvious. The evolution to a more energy conscious future will not be easy but, if the well being of future generations really is a prime concern to us, this is the enterprise that must be begun without delay.

Table 3: Relative uses of fuel in general terms (UK, 1988)

Usage	Percentage (%)	Energy (10^{10} W)
Residential and commercial	22.4	2.91
Industrial	37.2	4.84
Transportation	24.6	3.20
Conversion/transmission losses	15.8	2.05
Total:	100	13.00

Table 4: Earth-based world power sources and possible practical expectations

Source	Maximum output	Comments
<i>Regenerative sources</i>		
Photovoltaics	10^{15} W	For total world land coverage: 7–10% conversion efficiency REQUIRED: heavy duty storage system and higher conversion efficiency Land coverage difficulties Visual pollution
Biomass	9×10^{12} W	For total world land coverage: Land coverage and harvesting provide social problems
Wind power	6×10^{12} W	For total world land coverage: REQUIRED: heavy duty storage system Land coverage gives technical social problems Visual pollution
Wave power	Uncertain	Useful for communities near the sea: heaviest and most expensive of engineering
Hydroelectric generation	Uncertain (perhaps to 10^{12} W)	Restricted in global application
Tidal energy	Uncertain	Restricted to tidal regions
Geothermal sources	Perhaps 10^9 W	Restricted to specific areas (mid-ocean ridges very long term)
<i>High density sources</i>		
Nuclear power	10^{15} W or more	No more than 1K rise in environmental temperature: problems of waste disposal and of safety
Fossil fuels (some use is unavoidable)	10^9 W maximum allowable	Small application for special, local uses: pollution extraction essential

Present world requirement of about 2×10^{13} W perhaps rising to 10^{14} W



'THE POOL or a fixed contract?' This dilemma is now regularly facing energy managers when purchasing electricity. A fixed contract offers certainty of cash-flow. Pool related contracts may be cheaper in the long run, but prices are often very volatile.

A difficult choice.

Pool related contracts with a 'cap' can provide a compromise, but 'cap' prices have increased dramatically this year. Today's answer may be electricity forward agreements (EFAs) which enable customers on pool to benefit from low prices while choosing when, where and at what price to hedge their exposure to volatility.

EFAs are a new risk management tool, available to companies who wish to fix and minimise their exposure to electricity pool prices. They are designed to be used in conjunction with a customer's current pool-related electricity purchase contracts and should not be viewed as an alternative method of buying physical electricity.

Dealing is on an over-the-counter (OTC) basis, giving a great deal of flexibility to those energy managers who wish to fix their pool prices for specific periods of demand. EFAs themselves are cash-settled contracts for difference, with settlement based on electricity pool prices in England and Wales. Thus, EFA trading is straightforward for any company consuming in excess of 1MW.

In an EFA, two parties agree on the future price of electricity in the pool; if the actual price

Electricity forward agreements

A flexible route to cheaper power?

proves to be greater or less than agreed, the parties compensate one another for the difference. Risk management tools of this form have been widely used in the electricity supply industry since the creation of the pool, for the generators offer such contracts to the regional electricity companies (RECs). Additionally, the broad principles involved have been successfully employed in other commodity markets.

In summary, EFAs offer the advantages of speed, flexibility and anonymity up to the point of closing a transaction for wholesale purchasers of electricity to hedge their pool risk.

The new broking service was set up in October 1991 in response to requests from the electricity industry. An industry-wide group, including all the major regional electricity companies and the generators, designed the framework for the EFA market and asked GNI Ltd, a subsidiary of Gerrard & National Holdings Plc, to act as the initial broker; this framework has focused trading activity in the early stages, and has provided the market with the

generally accepted form of contract. The framework accommodates the daily movements in pool prices enabling users to hedge their exposure to anticipated peaks.

GNI matches trades between participants with complementary requirements; it does not trade as a principal in the new market. Prices and other information from GNI is gathered and distributed via the S&P ComStock system operated by ICV Ltd. However, participation in the EFA market can be effectively achieved with just a telephone and minimum resources.

The market has gradually built in activity since October, and is achieving progressively larger volumes. EFAs are now attracting interest from a wide spectrum of British industrialists many of whom have recently concluded their annual electricity contracts. EFAs are already changing hands for periods next winter.

Further information on EFAs can be obtained from James Hoare or Kevan Hull at GNI Ltd (Tel: 071 378 7171). □

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Out of date

'Tidal Power' by A C Baker A Review of the Book for Energy World

BINNIE'S have been the major consultancy firm involved in tidal work since interest in all renewable energies was rekindled in the mid-seventies, and Clive Baker has been at the centre of it; so he was an ideal author for this volume in the IEE series. He set out to cover the subject comprehensively: the physics of tides and water movement, alternative ways of capture, how to engineer the barrage components, environmental effects, and economics. It is an impressive sweep, and mostly it succeeds; even hardened practitioners will find they learn much from it, and will value its systematic presentation.

Yet parts of it are disappointingly out of date, if not erroneous. The introduction ('Acknowledgements') mentions the Severn Tidal Power Group (STPG), the first of the industrial consortia that took over project control and design initiative for the major UK prospective sites. We are told that this 1991 book's manuscript predated the STPG's latest 1989 report (EP 57): maybe so. Incompleteness is one thing, but conclusions that contradict current findings could have been covered by amendments at the proof stage.

As an example, take the treatment of flood pumping, pages 27 to 30. Baker is decidedly cool about it, mainly because a gain of 10% for Severn given by a flat (O-D) model turned out to be 2% in his 1-D model, due he says to dynamic effects. However STPG's 2-D model showed up compensating lateral motion, not represented in 1-D; and they reported an energy gain of 11% from flood pumping (EP 57, 2.3.2), any tariff effects being extra. Despite acknowledging (p 29) that his 2% result for Severn is inconsistent with La Rance's measured energy gain of 10%, and despite STPG's contrary conclusion, Baker supposes confusingly that tariff variations are the main argument for pumping.

Chapter 3 on machines assumes commercial arrangements as in a hydro-electric scheme ("the designer of a tidal scheme has to approach manufacturers ... etc", p 51). In fact tidal power really is different, as there is no direct control of reservoir level; water behaviour is dictated by nature, and each packet of energy must be extracted during the single tide that offers it or be lost for good. Moreover tidal amplitudes and times are constantly varying. The industrial consortia have learnt that with all those degrees of freedom design decisions (impeller profiles (hill charts), running speed, submergence, operating mode, etc) cannot be

segregated into two neat bundles on either side of a standard specification and tender. Optimisation is a combined effort, and the commercial arrangements must be adapted to suit.

Pressurising the generator cooling air (p 46) is not regarded as a good solution. Having atmospheric pressure may push out the inner water flow boundary, but the annulus area hardly changes and head loss is small; it also simplifies generator details, and allows access inside the bulb with the machine running. STPG's generators are unpressurised (EP 57, 2.3.1).

The chapter on economics has an aged ten-year-old flavour (the Severn figures on Table 11.1 are from the 1981 report!) and may strike the modern reader as simplistic. Most of the section on "costs" is about the components of capital cost; the consequent annual charge is seen one-dimensionally, ie in terms of interest rate alone (in just three paragraphs on p 190). The other section on "value" covers competitiveness with other forms of generation, and the role of discount rates in public sector investment.

Things have changed, and people now realise that project economics depend critically on where the money is coming from, especially where capital dominates as in renewables. Even Treasury opinion has evolved in ten years; as for borrowing from the private sector, costs are determined by the market's view of risk, of what the return has to be and how soon. It is all rather volatile and beyond the scope of a book of this kind. But it could have been mentioned, and some sort of warning given.

All in all, a worthwhile review of tidal power, but spoilt in parts where the author is too much preoccupied with out of date information.

P C Warner

Disappointing

Jahrbuch 92: VDI Gesellschaft Energietechnik Published by VDI-Verlag, Düsseldorf, 1992, 440 pp.

AS A yearbook this publication of the energy division of the German engineers' association is somewhat disappointing. Unlike the Institute of Energy's own yearbook, which combines a directory of information sources and buyers' guide, the VDI yearbook is essentially an anthology of technical papers presented at the various meetings of the energy division during 1991. These occupy some 380 pages. The rest of the book gives information about the energy division and its working groups, the various conferences and seminars planned for 1992 and VDI-GET publications. Also included

here are the VDI's submissions to Parliament on the future of energy in former East Germany and a summary of energy statistics (former West Germany only) supported by a detailed Sankey diagram valid for 1990. Two of the VDI-GET's publications are available in English: AVR-Experimental High Temperature Reactor (379 pp, 128 DM) and Superconductivity in Energy Technologies (278 pp, 158 DM).

The Yearbook and other VDI-GET publications can be obtained from: Verein Deutscher Ingenieure, VDI-Gesellschaft Energietechnik, Graf-Recke-Str. 84, Postfach 10 11 39, 4000 Düsseldorf 1.

Alan Field

Recently published

'The Glass Container Industry'

Energy Efficiency Office Best Practice Programme Guide 27. Free of charge (UK only) from The Energy Efficiency Enquiries Bureau, Building 156, Harwell Laboratory, Didcot, Oxon OX11 0RA. Tel: 0235 436747; fax: 0235 432923.

'Hazop and Hazan'

by Trevor Kletz, The Institution of Chemical Engineers, Rugby, 150 pp, £23.50. Available from Book Sales, IChemE, 165-171 Railway Terrace, Rugby CV21 3HQ. Tel: 0788 578214; fax: 0788 560833.

'European Directory of Renewable Energy Suppliers and Services 1992'

edited by Bruce Cross, James & James (Science Publishers) Ltd, London, 360 pp, free to those who buy/specify renewable energy equipment, extra copies £24.95. Available from James & James, 5 Castle Road, London NW1 8PR. Tel: 071 284 3833; fax: 071 284 3737.

'Development of the Oil and Gas Resources of the UK' ('The Brown Book')

Department of Energy, 152 pp, £30.00. Available from DEN Publications, PO Box 30, Alton, Hants GU34 4PX. Tel: 0420 22050; fax: 0420 22642.

'Environmental Law: A Practical Handbook'

by John Garbutt, Chancery Law Publishing Ltd, London, £18.95 plus £2.50 p&p. Available from leading bookshops or from Chancery Law Publishing Ltd, 22 Eastcastle Street, London W1N 7PA.

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To the rescue

THE Engineering Council in May put forward an eight-point plan to rescue the subject of technology in the national curriculum which, it says, is "a mess".

The Council says that an analysis of research carried out for it by Professor Alan Smithers and Dr Pamela Robinson, of Manchester University School of Education, shows that the technology being taught in secondary schools is very different from what was originally intended.

Technology as it has emerged in schools — as the educational successor to craft — is different from technology as it is commonly understood, that is, inventing or improving things through the application of science and maths.

Her Majesty's Inspectors of Schools are reporting that the standard of work in the subject in secondary schools is actually declining, says the report, in contrast to other subject areas where improvements have been noted.

It is proving extremely difficult to devise the required standard assessment tasks (SATs) in technology; those for age 14 have already been scrapped and put out to new contract along with the other SATs for that age group. And there are grave doubts about those for seven-year-olds due this summer.

In the Engineering Council report *Technology in the national curriculum*, published today, Professor Smithers and Dr Robinson report on their examination of documentary evidence, visits to schools, and interviews with policy-makers, inspectors, advisers, employers, teachers, teacher trainers, curriculum developers and parents. Their research was partly sponsored by BP.

They say: "Many of the difficulties being encountered seem to be associated with a progressively generalised and abstract notion of 'technology'."

The character of 'technology' as a subject in the national curriculum changed considerably over the two years of the consultation process prior to the introduction of the subject, says the report. As well as craft, design and technology the new subject has now come to include home economics, business studies, art and design and information technology.

From being essentially about 'designing and making' the subject has become generalised problem-solving without a specified knowledge base, says the report.

It goes on: "The problem with technology in the national curriculum can be stated very simply: It lacks an identity. The first step towards rescuing it would seem to be to delimit it as a subject saying what technology is and, just as important, what it is not."

The Engineering Council's eight-point rescue plan says:

- technology should be clearly established as a practical/technical subject concerned with the design and manufacture of products and systems;
- its content should be specified as a practical organisation of knowledge and skills;
- it should be distinguished from the overlapping but different areas of basic life skills and vocational education;

- there should be clear progression in content with the subject acting as a stepping stone to higher education and employment;
- curriculum materials should be devised to reflect this sharper focus;
- the tests and examinations should embody the objectives and content as more precisely specified;
- the success of technology as redefined will depend on a supply of appropriately qualified teachers supported by good in-service education;
- the subject will also require appropriate capitation, resources, workshop facilities and ancillary staff.

The Engineering Council says that the National Curriculum Council should be urged to think again about attainment targets and programmes of study for the subject. It adds that the revised national criteria for GCSE Technology is still to be published and the School Examinations and Assessment Council should be pressed to issue criteria reflecting the concerns now expressed.

The report concludes: "Britain is the first country to make technology part of the compulsory curriculum for all pupils aged 5-16. It is a pioneering venture and some false starts are perhaps inevitable. It does, however, seem to be going badly wrong at the moment and action is needed now. Getting technology right in schools would bring benefits to the education of individuals, the economy and ultimately the quality of life for us all."

Mr Denis Filer of The Engineering Council says that the report was commissioned because he had become increasingly alarmed at the level of concern about the development of school technology expressed by teachers, students, parents and educationalists.

As a member of the original national curriculum working group he felt that he had an obligation to understand what had gone wrong and what should be done. Mr Filer says in a foreword to the report: "Action needs to be taken now if technology is to be a valuable part of the education of our children and if it is to be given credibility and respect among the community at large and with industry."

'The other half'

CAREER breaks for women engineers and technicians are being promoted through a new version of the video 'The Other Half', launched in May by The Engineering Council.

Sir Geoffrey Holland KCB, Permanent Secretary at the Department of Employment, who sponsored the video, said "Equality of opportunity is vital both in terms of women's rights and if the country is to meet the skills shortages of this decade."

Sir Geoffrey went on to emphasise the importance of flexible working practices which will allow women to combine their careers with domestic commitments.

Joanna Foster, Chair of the Equal Opportunities Commission, backed up Sir Geoffrey by saying that if Britain is to face up to the challenges of the single market, it cannot afford to waste the skills, brainpower and creative energies of British women. Ms Foster said that a

change of attitude towards women working in engineering was required in order to retain the best of British women.

She went on to describe how, over the last 10 years, the WISE campaign had actively increased the numbers of young women wanting to pursue careers in science and engineering. The challenge remaining to employers, she emphasised, was to retain these young women, particularly when they became mothers. The introduction of career break policies and schemes is just one method of achieving this aim. Career break schemes should, however, be just part of an overall equal opportunity programme which looks at other changes needed in both the working environment and working practices which are more flexible and more family orientated.

"Employers," continued Ms Foster, "should be urgently reviewing their sexual harassment policies to ensure the culture in which an increasing number of women are now working is not off-putting and encourages them to stay."

Denis Filer of The Engineering Council said that the video was essential viewing for all employers. He maintains that training and retaining women along with flexible working conditions were all essential components of a satisfactory workplace. He added that although there has been a marked increase in women studying engineering (15%), he would not be happy until the figure neared the 50% mark.

The 15-minute video outlines the reasons why employers should provide career break opportunities for women engineers and technicians. These opportunities would benefit not only the women, but employers themselves. It depicts women engineers and technicians telling of their experience before, during and after a career break. In addition, leading British industries point to the benefits of this career structure for women.

Environment code proposed

A NEW *Code of Good Practice for Engineers and the Environment* is to be introduced by The Engineering Council. The code will propose a series of practical steps to help engineers integrate the new environmental imperatives into all areas of their work.

An 'embryo' version of the code was issued in May as a discussion document to all interested parties including: the professional engineering institutions, representative engineering bodies, and the industry affiliates of The Engineering Council. Responses to the code of good practice are being invited by late September.

The 'embryo' Code — which takes the International Code of Environmental Ethics for Engineers as its starting point — will also be presented to the Engineering Assembly being held at Churchill College, Cambridge, in July this year. Elected members of the assembly represent the 290,000 professional engineers and technicians registered with the Council, to whom the code will eventually apply. It is expected it will come into effect in 1993.



June 1992

The legal implications of waste to energy projects

Conference, 24 June, London.
Details from IBC Legal Studies & Services Ltd, IBC House, Canada Road, Byfleet, Surrey KT14 7JL. Tel: 071 637 4383; fax: 071 631 3214.

The Clifford Paterson

Lecture: Magnetohydrodynamics in material processing

25 June, London.
Details from The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG. Tel: 071 839 5561, ext 203.

Utilities regulation

Conference, 26 June, London.
Details from IBC Legal Studies & Services Ltd, IBC House, Canada Road, Byfleet, Surrey KT14 7JL. Tel: 071 637 4383; fax: 071 631 3214.

August 1992

SynOps 92

Conference, exhibition, technical programme & tour, 31 August-4 September, North Dakota, USA.
Details from Dawn Botsford, Symposium Co-ordinator, tel: (701) 777 2663; fax: (701) 777 4282.

September 1992

1992 ASME Cogen Turbo Power

Congress & exposition, 1-3 September, Houston, Texas, USA.
Details from The International Gas Turbine Institute, 6085 Barfield Road, Suite 207, Atlanta, Georgia 30328, USA.

Air distribution in rooms

International conference, 2-4 September, Aalborg, Denmark.
Details from: Danish Association of HVAC Engineers, Orholmvej 40 B, DK-2800 Lyngby. Tel: +45 42 87 76 11; fax: +45 42 87 76 77.

Role of oxygen in improving chemical processes

Conference, 7-9 September, Paris, France.
Details from Dr John F Gibson, Secretary (Scientific), The Royal Society of Chemistry, Burlington

House, London W1V 0BN. Tel: 071 437 8656; fax: 071 437 8883.

Heat pumps, theory and application

A short course for lecturers, 7-11 September, Worcester, UK.
Details from BNCE, 30 Millbank, London SW1P 4RD. Tel: 071 834 2333, ext 6339.

Jet cutting technology

11th international conference, 8-10 September, St. Andrews, Scotland.

Details from Miss Tracy Peters, Conference Organiser, BHR Group Ltd, Cranfield, Bedford MK43 0AJ. Tel: 0234 750422; fax: 0234 750074.

Uranium Institute's 17th annual symposium

9-11 September, London.
Administration details from Concorde Services Ltd, 10 Wendell Road, London W12 9RT. Tel: 081 743 3106; fax: 081 743 1010; programme details from Uranium Institute, 12th Floor, Bowater House, 68 Knightsbridge, London SW1X 7LT. Tel: 071 225 0303; fax: 071 225 0308.

EIA trade mission to Indonesia

11-19 September.
Details from Anna Small, Export Director, Engineering Industries Association, 16 Dartmouth Street, London SW1H 9BL. Tel: 071 222 2367; fax: 071 799 2206.

2nd World renewable energy congress

13-18 September, Reading, UK.
Details from Prof A A M Sayigh, WREC, Dept of Engineering, University of Reading, Whiteknights, PO Box 225, Reading RG6 2AY. Tel: 0734 318588; fax: 0734 313835.

Electrical and control aspects of the Sizewell B PWR

International conference, 14-16 September, Cambridge, UK.
Details from IEE Conference Services, Savoy Place, London WC2R 0BL.

Turbomachines: turbo-compressors in industrial use II

Conference, 15-16 September, Hanover, Germany.
Details from VDI-Gesellschaft

Energietechnik, PO Box 10 11 39, W-4000 Dusseldorf 1, Germany. Tel: *49 211 6214-414.

Energy economy 1992

Conference and trade show, 15-17 September, Maastricht, The Netherlands.
Details from the Conference Secretariat, Vereniging, Krachtwerktuigen, PO Box 165, NL-38000 AD Amersfoort, The Netherlands. Tel: +31 33 602 506; fax: +31 33 602 505.

Geotech '92

Symposium and exhibition, 16-19 September, Tokyo, Japan.
Details from Geotech Secretariat, c/o World Import Mart Co Ltd, 3-1-3 Higashi-Ikebukuro, Toshima-ku, Tokyo 170, Japan. Tel: +81 3987 3161; fax: +81 3981 8371.

Emission driven flame technology

Conference, 21-22 September, Sheffield, UK.
Details from Prof N Syred, School of Engineering, UWCC, Cardiff. Tel: 0222 874318.

Incineration and energy from waste

Short course, 21-23 September, Leeds, UK.
Details from Mrs Sheila Speedy, Dept of Continuing Professional Education, Continuing Education Building, Springfield Mount, Leeds LS2 9NG. Tel: 0532 333241; fax: 0532 333240.

1992 International symposium on radon and radon reduction technology

22-25 September, Minneapolis, USA.
Details from Pat Heightchew, CRCPD, 205 Capital Avenue, Frankfort KY 40601, USA.

Hydrocyclones

International conference, 23-25 September, Southampton, UK.
Details from Mrs Kit Stones, Conference Organiser, Hydrocyclones, BHR Group Ltd, Cranfield, Bedford MK43 0AJ. Tel: 0234 750422; fax: 0234 750074.

Annual conference of the Women's Engineering Society

25-27 September, York, UK.

Details from Anita Meldrum, c/o Esmil Ltd, Smithfield House, Blonk Street, Sheffield, S1 2AU. Tel: 0742 780899.

2nd International cokemaking congress

28-30 September, London.
Details from Ms J Upton, Conference Dept, The Institute of Materials, 1 Carlton House Terrace, London SW1Y 5DB. Tel: 071 839 4071; fax: 071 976 3576.

Combustion fundamentals

Course of 20 post-experience lectures, 28 September-2 October, London.
Details from Prof F J Weinberg FRS, Dept of Chemical Engineering & Chemical Technology, Imperial College, London SW7 2BY. Tel: 071 589 5111, ext 4360/4498.

Plovdiv Autumn Fair

28 September-4 October, Bulgaria.
Details from Peter Moist, tel: 021 455 9600; fax: 021 456 1785.

October 1992

Intelec

International telecommunication conference, 4-8 October, Washington DC, USA.
Details from Intelec 92, 291 Springfield Avenue, Suite 110, Berkeley Heights, NJ 07922. Tel: fax: +1 908 469 3430.

11th CERI international oil & gas markets conference

4-6 October, Alberta, Canada.
Details from CERI Conference Division, tel: (403) 282 1231; fax: (403) 289 2344.

Risk management

International conference, 5-9 October, London.
Details from HSE, Baynards House, 1 Chepstow Place, Westbourne Grove, London W2 4TF. Tel: 071 243 6000; fax: 071 727 6268.

InPower 92

Conference & exhibition, 6-7 October, Sunbury-on-Thames, Surrey, UK.
Details from FMJ International Publications Ltd, Queensway, Redhill RH1 1QS. Tel: 0737 768611; fax: 0737 761685.



1992 WORLD RENEWABLE ENERGY CONGRESS

For further information contact:

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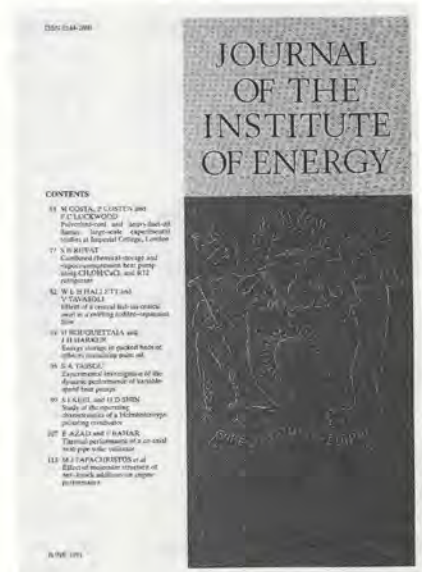
Reading, United Kingdom
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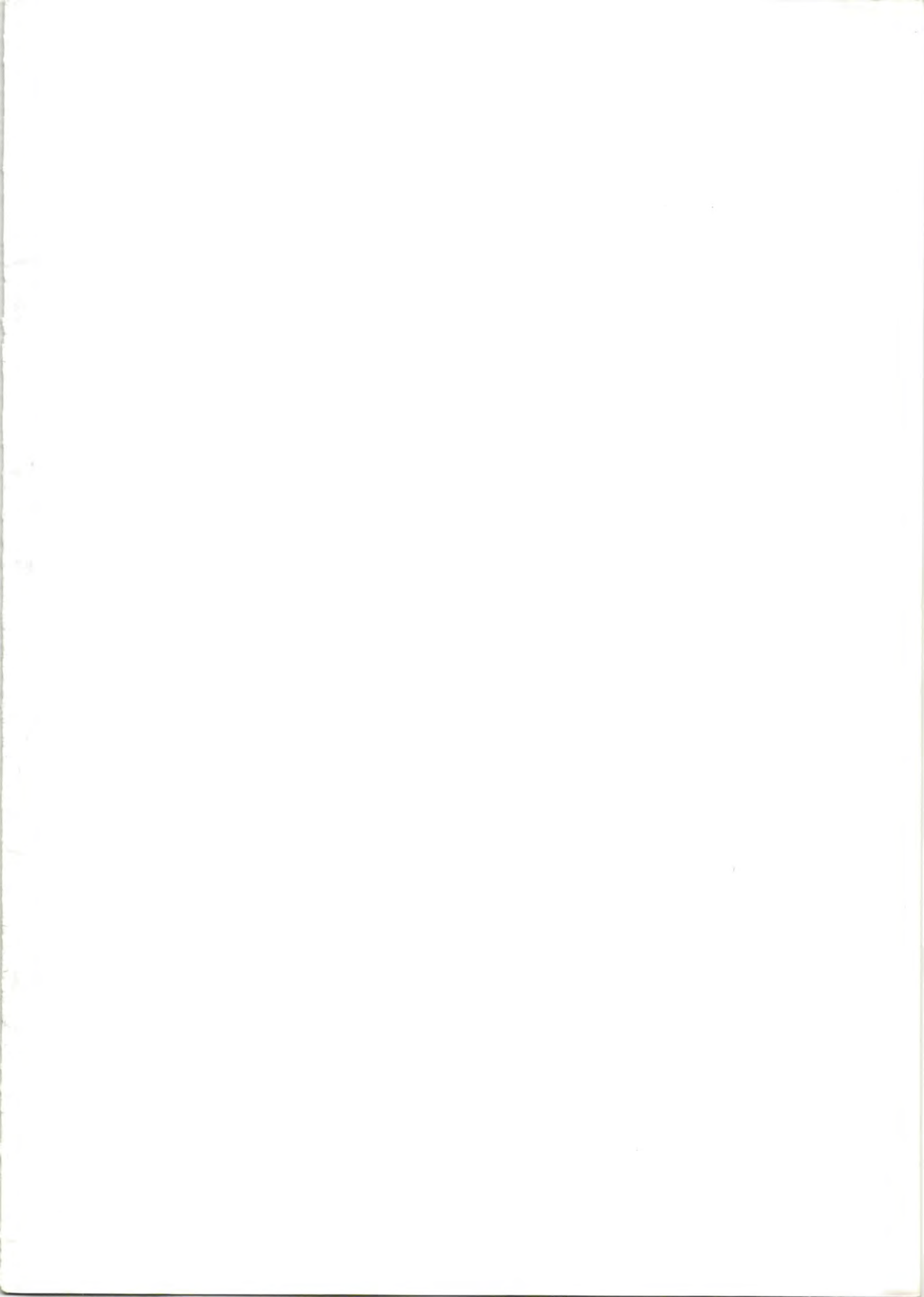
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Examples of papers recently published include: *Three-dimensional modelling of the Sheffield solid-waste incinerator* (V Nasserzadeh, J Swithenbank and B Jones); and *Reduction of N₂O by gas injection in CFB boilers* (B Leckner and L Gustavsson).





INSTITUTE OF ENERGY CONFERENCES



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

For further details please contact the Conferences Department,

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1992

15 October **UK COAL '92 — OPPORTUNITIES FOR TRADE**
Venue: The Cafe Royal, London
Chairman: Dr A W Cox (*UK Coal Review*)

25 November **ENERGY TRANSPORT & THE ENVIRONMENT**
Venue: The New Connaught Rooms, London
Chairman: Prof Tony Ridley (Institute of Energy)

1993/94 Proposed Programme (titles to be confirmed):

- **REGULATING THE ELECTRICITY INDUSTRY — THE WAY FORWARD**
- **CARBON TAXES**
- *2nd International Conference on*
CERAMICS IN ENERGY APPLICATIONS
- **MITIGATION OF GREENHOUSE EMISSIONS**
- **ENERGY FROM WASTE — Scotland**
- **CLEAN ENERGY TECHNOLOGY & THE NFFO**
- **ENERGY MANAGEMENT**
- **THE DASH FOR GAS**

Conferences co-sponsored by The Institute of Energy

23 June **Gas Metrology: Metering Systems for large gas supplies to industry and power stations**
Venue: British Gas Commercial Centre, London W1
Contact: David Suthers, CEA on tel: 0685 879119

14-16
September **Electrical & Control Aspects of the Sizewell B PWR**
Contact: Sheila Griffiths, IEE on tel: 071 240 1871

5 November **Civil Engineering Aspects of Combined Cycle Gas Turbine Projects**
Contact: Carol Chin, IoCE on 071 839 9803

1993

22/23 March **3rd International Conference on Desulphurisation**
Contact: IChem E on 0788 578214