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ATOM

"PERSPECTIVES" RE-EXAMINED

WHITHER THE "RENEWABLES"?

BOOK REVIEWS

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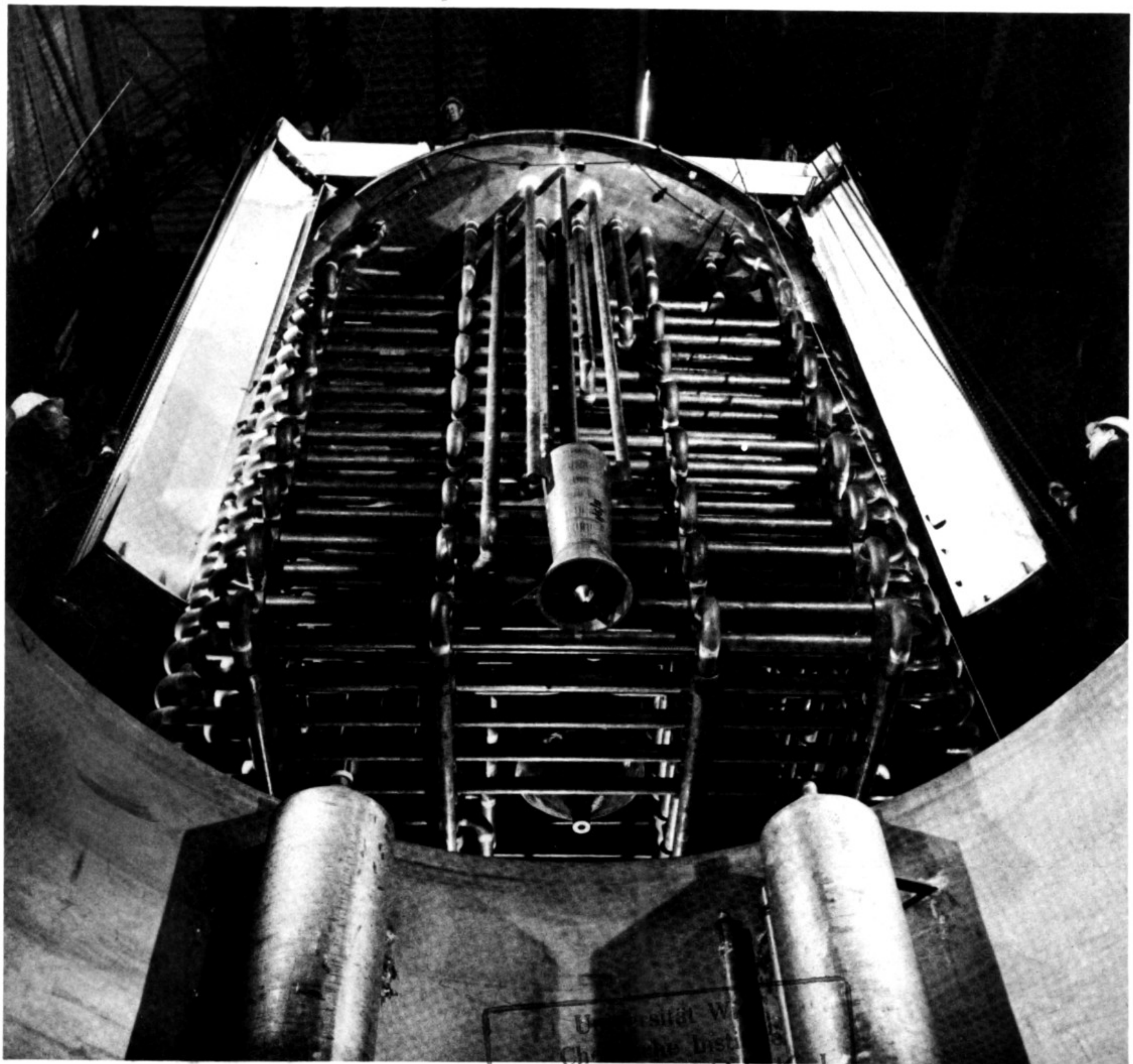

DECEMBER 1980 NUMBER 290

ATOM contents

THE MONTHLY INFORMATION BULLETIN OF
THE UNITED KINGDOM ATOMIC ENERGY AUTHORITY

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Front cover: The cooling coils of a storage tank for highly radioactive fission product waste before insertion into a newly completed tank at the Windscale works of British Nuclear Fuels Ltd. BNFL announced on 5 November that if negotiations with the French can be completed successfully it is probable that the first production plant for the vitrification of highly active waste at Windscale will be based upon the AVM process developed at Marcoule. In this issue, "perspectives" for the management of radioactive waste are re-examined *BNFL*

"PERSPECTIVES" RE-EXAMINED

Two conferences close in time but far apart in their technical content have been held in London in the past few months, both under the same title—radioactive waste management in perspective. The first was a one-day symposium organised jointly by the National Radiological Protection Board and the British Association for the Advancement of Science, in June; the second was a similar one-day conference chaired by Professor Bryan Harvey, chairman of the Major Hazards Advisory Committee, in September. James Daglish reports

The NRPB has now published a synoptic report of the first meeting*, whose declared aim was to allow those professionally involved in radioactive waste management to tell others about their work, and in return to learn something of the way in which their work is viewed in society as a whole. The symposium was something of a curate's egg—good in parts. The report editor, Marion Hill of the NRPB, wrote in her summing-up:

> "I had hoped that the symposium would be a forum for a wide-ranging discussion of the more controversial aspects of waste management. Many of the topics which are receiving considerable attention in radiological protection circles were covered in some detail in the papers presented here. Yet few of them were taken up in discussion. This may have been a result of the unfamiliarity of many of the ideas. If this is the case then there has been a failure in communication between the 'experts' and the 'public'. The symposium went some way towards rectifying this situation . . . ."

—as indeed it must have done, for those attending were drawn from both Houses of Parliament, representatives of local authorities, public groups, trades unions, Government departments, universities, the nuclear industry and the press, and a good number of individuals known to be concerned with the subject.

The pity of that first meeting though was that the level of papers and discussion seemed never to hit quite the right note. Yet the meeting was still useful, in that it did enable people from opposite sides of the fence to peer into each other's gardens.

The second conference was I thought more successful, in that the papers were at a uniform high level and matched their audience; but one could have searched all day among the participants for people opposed to nuclear power, or people who simply feel uneasy about current proposals for radioactive waste management. A "perspective" was drawn clearly—but only for those who were there to see it.

Objectives

In the first paper C.B. Cope and Dr G.B. Briscoe, from the Birmingham Radiation Centre, University of Birmingham and from the Department of Chemistry, University of Aston in Birmingham respectively, described the fundamental objectives in the management of radioactive wastes: to ensure that neither process operators nor the public at large receive radiation doses in excess of their respective dose limits. The doses must be kept as low as is reasonably achievable in accordance with the general principles of radiological protection. The authors made the point early on that all industries produce wastes which have no realisable value, and the nuclear industry is no different from hundreds of others in this respect; but the nuclear industry must meet and be seen to meet stringent and particularly exacting waste management standards.

Public concern and governmental research in Britain, they said, is centred on the problem of treatment and safe disposal of high-level liquid radioactive wastes, but there is less awareness of other waste management aspects of the nuclear power industry. Other large areas which warrant detailed attention, in their view, are the disposal aspects of uranium mill tailings (not a problem in the UK, but certainly requiring attention in uranium producer countries); the substantial volumes of intermediate level wastes which have no established treatment and disposal technology; the accumulation of high-level solid wastes from fuel element decladding; and the substantial volumes of active waste which will be produced during the next few decades as a result of plant decommissioning.

"Whilst it is recognised that almost every manufacturing industry produces waste in the form of by-products, disused plant or derelict land, the nuclear power industry, if it is to prove the energy source our nation requires, will need to demonstrate effectively and persuasively that these problems have been solved," the authors wrote. "The cost incurred (or predicted) needs to be absorbed into present-day pricings to ensure that the required finance is (or will be) available from within the industry when these contingent liabilities have to be faced."

Professor J.R. Greening, of the University of Edinburgh, presented a paper on the health effects of ionising radiation and the likely impact of radioactive waste disposal, confining his discussion to high-level waste and assuming that it will at some time be buried deep underground. How might it return to man?

Prof. Greening recalled that the NRPB had analysed this question in its report *Preliminary assessment of the radiological protection aspects of disposal of high-level waste in geologic formations* (R-69, 1978). By far the most likely route was found to be that arising from groundwater reaching the radioactive waste, leaching it out of its containment, and eventually coming to the surface bringing some of the activity with it. Here, it would be diluted with other water and might enter drinking water supplies. In addition, man might eat freshwater fish from rivers or lakes into which the groundwater flowed, or might eat products produced on land irrigated by this groundwater. Finally, he might eat fish from the sea into which the groundwater eventually emptied. Analysis showed the groundwater route to be substantially greater than any of the others. Other disposal routes had been investigated similarly. Finally, an INFCE working group had concluded (on a number of assumptions) for example that from a repository underground containing waste from 100 gigawatt-years of electrical energy production the most exposed group might receive a maximum dose, millions of

*Published as a supplement to the NRPB *Radiological Protection Bulletin* No.36, September 1980.

Laboratory preparation of simulated highly active waste for vitrification, at the Windscale works, in Cumbria, of British Nuclear Fuels Ltd

years hence, of at most a few per cent of that from natural sources. Although the analysis was limited by the accuracy of the model used by the INFCE group, "the uncertainty was not such as to affect the conclusion that disposal can be carried out without undue risk to man or the environment."

Commonsense

All that was very fine. Papers presented at the conference dealt with the work being done worldwide on the conversion of high-level waste to solid forms – incorporated in glass, ceramics, synthetic rock and other materials. Could we be sure that it would not get out within the first several hundred years of its decay – the period during which its activity would be greatest?

"My old chemistry master at school used to ask the question 'Does marble burn?' and then go round the class until some boy, either through ignorance or a desire to please, answered 'yes' – whereupon would come the tart comment 'Have you ever seen a tombstone on fire?'," said Prof. Greening. "The purpose of this little ploy was to indicate that many scientific questions could be answered by the application of commonsense and keen observation." Archeological discoveries tended to support the view that glasses and some metals could survive for long periods: "the ancient Egyptians had the biochemistry and other technology to make a fair job of preserving a human body for 5 000 years. If they could do that surely we can keep a glass block reasonably dry for a lesser period."

Prof. Greening continued: "What of the period beyond a few hundred years? Although the containment may well survive for a very extended period one must examine the likely consequences of eventual failure. Again I shall try a commonsense approach.

"Firstly, one can compare the potential hazard of the waste with that of the uranium ore from which it was produced. After about 4 000 years the waste has three times the potential toxicity of the ore from which it was produced, and after 10 000 years it has the same toxicity as that ore. This should surprise no one as by then it almost entirely *is* the original ore. Thermal reactors use only a fraction of 1 per cent of the original uranium. It might be said that we are mining ore in one place and burying it in another where it is almost certainly safer than where it started because of the effort we will have made for its containment.

"Alternatively, in the case of land burial we can compare the activity of the waste with the natural activity of the rocks above the point of burial. Suppose the rock is granite. Granite contains about 4 parts per million or uranium-238 and 13 ppm of thorium-232. If these are in equilibrium with their daughter products there will be about 2×10^5 curies of natural actinides per cubic kilometre of granite. I doubt whether it is widely appreciated just how much natural radioactivity there is in the ground beneath us.

"The NRPB has estimated that by the year 2000 the UK will have accumulated waste corresponding to the production of 330 GW years of electrical energy. This waste, after decaying for 1 000 years, will contain 9×10^5 Ci of actinides. Thus 5 km^3 of granite will contain as much *natural* actinide activity. If the waste is buried at a depth of 1 km, then a 5 km^2 area of overlying granite will contain as much actinide activity – in other words, an area about 1½ miles square. This volume of granite will also contain about 8×10^7 Ci of naturally radioactive potassium-40. This is about 400 times the fission product activity remaining in the radioactive waste."

Prof. Greening went on to make the same sort of calculation for disposal on or under the sea bed. He acknowledged that there are limitations to the commonsense approach, and that it is necessary for bodies such as the NRPB to make the detailed analyses they do. Nonetheless, commonsense did show that it should be possible to contain radioactive waste for a few thousand years, and that thereafter it would be no more hazardous than the ore from which it originated. Even if the waste escaped from its burial site, in itself a point of doubt, it would make only a tiny change to natural background radiation.

"Mankind has always lived with this, and I do not think anyone worries about it," he said. "It varies with time at any one place, depending on such things as recent rainfall and changes in atmospheric pressure. It varies very much more from place to place, but I have never heard of anyone moving from a high to a low background area [to escape radiation exposure].

"At one time I was worried about radioactive waste, but the more I have learned – and in particular the more I have put numbers into the problem – the more reassured I have become. Seen in the perspective of naturally occurring radioactivity the problem appears to be manageable, although many detailed data remain to be more accurately determined."

I cannot hope in this report to deal in detail with each paper. The next, by F.H. Passant, head of the Active Waste Project, Generation Development and Construction Division, CEGB, and R.B. Pepper, principal health physicist in the CEGB Health and Safety Department, described CEGB practice in the management of wastes arising at CEGB nuclear power stations.

Dr L.E.J. Roberts, Director of AERE Harwell, then described high-level waste production and management in Britain in terms familiar to ATOM readers: *see,* for example, *Radioactive Waste – Policy and Perspective,* ATOM No.267, January 1979. [It is proposed that this latest paper should be used as the basis for a separate booklet, as was the first.]

Dr Roberts stressed a basic principle in high-level waste management: that the sequence and most importantly the timing of operations is determined by the amount and decay characteristics of the constituents of high-level waste, and the resulting heat output. Most of the activity in spent fuel arises of course from fission products of the shortest half-lives; reprocessing and vitrification would not occur until several years after the discharge of the fuel from the reactor, during which time the activity of the short-lived species would have decayed. The activity of vitrified waste would then be dominated by the decay of strontium-90 and caesium-137 with half-lives of about 30 years. Between 300 and 3 000 years the americium-241 content would dominate; the decay product of Am-241 is neptunium-237 with a half-life of two million years, which becomes the predominant, alpha, activity at very long times—although on this timescale the total activity present will have decayed to very low levels indeed.

"Various suggestions have been made that the long-lived actinides might be destroyed by nuclear transmutation processes in a reactor in a manner parallel to that of the burning of plutonium," said Dr Roberts. "In such a process the actinides would be replaced by fission products in substantially the same proportions as those resulting from the burning of uranium and plutonium in our present reactors. The very complex chemical separation processes needed to separate the actinides from the rare earth fission products, the fabrication of special fuel elements and the reactor physics of their transmutation are regarded as feasible to the extent that potential solutions to the technical problems involved have been identified. However, a very large research and development programme would be required over several decades before industrial-scale operation could be considered as practicable and the consensus view is that the reduction of risk in the long term would be marginal, in comparison with disposal into suitably selected geological formations, and probably offset by increased risk associated with increased exposure of operators of plant and the production of additional volumes of low-level wastes."

A major consideration in the management of high-level wastes was their heat output, said Dr Roberts. This decayed with the same characteristic half-lives as the radioactivity. Immediately after vitrification a period of cooling would be required if the waste had been solidified within the few years after fuel discharge from the reactor, in order to limit the centre temperatures of the glass blocks to obviate the possibility of devitrification and also to reduce the heat output from the blocks to limits that could be tolerated within a repository. Temperature limits would be set by the thermal stress that could be tolerated, depending both on the rock temperature adjacent to freshly-emplaced waste containers and on the bulk rock temperature reached over the volume of the repository as a whole. Considerations of the convective flow of groundwater caused by a temperature gradient within the rock body were also relevant. Theoretical and field studies were in hand, and it was too early to say precisely what the safe maximum temperatures might be for different forms of rock; for planning purposes a temperature limit of 100°C had been assumed as a reasonably conservative estimate. Given this temperature limit a number of designs of both stores and repositories could be developed by varying such parameters as waste content and block spacing.

Initially, however, there were considerable technical and safety advantages in storing the vitrified waste in a store with simple cooling before final disposal to a repository which could be sealed and which required no further surveillance:

- the integrity of the canning and/or over-cladding could be observed over a considerable period, and remedial measures taken if necessary;
- in a store which could be kept dry there was no credible mechanism by which the activity could spread back into the environment and the inspection needed would be minimal. The waste form would not be attractive to "wrong-doers"; dispersal would be a very difficult operation.
- The waste blocks in their containers could be monitored and inspected during the period of maximum heat emission and consequent maximum temperature gradients;
- no waste blocks would ever be subjected to high temperatures in a final repository, so that corrosion and leaching would be limited; and
- geological safety need not be proved under artificial conditions of high local temperatures.

Talking about safety

The conference reported here was preceded by a similar meeting the previous day, at which the subject was the safety of nuclear power installations. The discussion ranged widely, from a consideration of whether the world needs nuclear energy at all to near-philosophical debate on how the industry might improve its communications—both between those actually engaged in work in the industry, and between them and the general public.

The first lesson—from the Three Mile Island incident—was drawn by G.M. Jordan, of the UKAEA's Dounreay establishment, who saw a need for clear recognition of the importance of public perception. This perception, he argued, derived not from a balanced objective examination of technical factors but from intensely subjective value judgments; and he quoted Alan Wyatt, a former vice-President of CANATOM:

> **"One major mistake often made by the technical community is to assume that it is the technical merits or otherwise of the technology that are the real and only subjects of scrutiny. That is very often peripheral; the heart of the matter is social and political, it is much more related to values, life styles and dictates of the heart, not the head."***

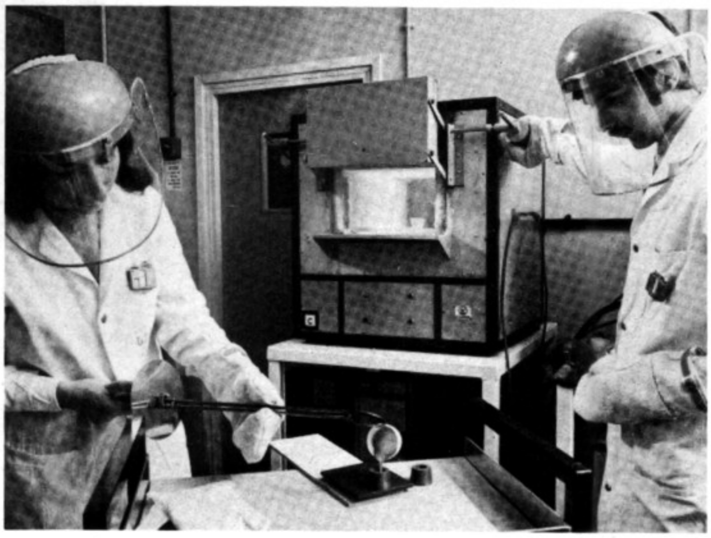
Mr Jordan went on: "TMI has justifiably been described as a communications disaster which did grave harm to the industry's image. The public communications network rapidly saturated and became unavailable to State and Federal agencies having responsibility for the protection of the public. Highly contradictory statements on the current and future status of the plant were provided from a number of sources, thus creating a picture of total confusion which seriously undermined public confidence. Large gaps in the flow of authoritative information were filled in by the less responsible sectors of the media from commentators who had no significant knowledge of the incident in particular and nuclear technology in general.

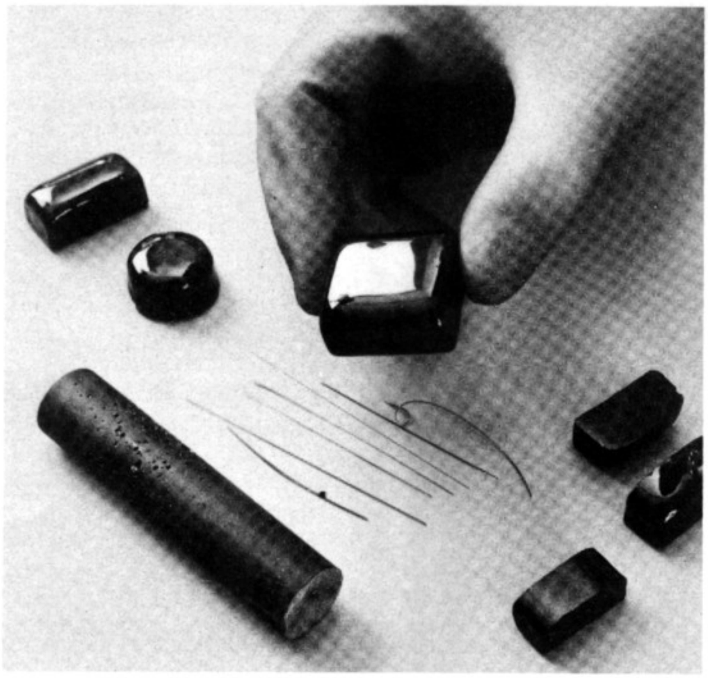
"The lesson can be summarised in a phrase: effective pre-planning."

Mr Jordan noted that in September 1977 the Davies-Besse Unit 1 had suffered an incident of almost uncanny similarity to TMI. There was a loss of feedwater, the steam generators boiled dry, the emergency relief valve opened and stuck, and so on. "The author ventures to suggest that the details of Davies-Besse may not be known to a number of nuclear specialists," he said drily. "If this is so it is a commentary on the adequacy of our methods for the dissemination of experience. It indicates the need for data to be provided in a *structured* form to allow busy designers and operators to interrogate the sources for information relevant to their current problems. What is required is not more reporting, but more effective collation and dissemination."

The lessons from TMI were many and various; they had been taught not at the expense of human life or even measurable damage to the environment, but at the expense of damage to the reputation of an industry which has always held the preservation of safety as its paramount duty. Mr Jordan recalled a remark made by Lord Hinton many years ago, to the effect that unlike many other engineering enterprises the nuclear industry could not afford the luxury of learning by making mistakes. "If, despite our endeavours, mistakes do occur we must certainly not overlook the imperative of learning from them," he said. "The nuclear industry's response to TMI has been swift and objective and demonstrates that this lesson has been well assimilated."

***ATOM No.286, August 1980, p.208.**





The casting of molten, simulated highly active waste samples at BNFL's Windscale works (above) and (right) samples prepared for testing of their durability. The "waste" is incorporated in a borosilicate glass *BNFL*

"Perspective" again

Dr Roberts, like Prof. Greening, turned in the final section of his paper to comparisons. Three periods could be distinguished in the management of high-level waste, he said. First, a period when artificial cooling was desirable. This period should extend until at least 50 years after discharge from the reactor, and it might even extend to a period of between 100 and 200 years, after which time the heat emission would have fallen to low levels and the subsequent cooling rate was slow. Secondly, a period of several thousand years at least during which activity could be confined by the engineering of the container and overpack material and by the durability of the glass waste form itself; and thirdly a subsequent period in which the activity would have fallen to comparatively low levels and the decay was slow, dominated by a few species of long half-life.

Human factors

Dr D. Embrey, of the Department of Applied Psychology at the University of Aston in Birmingham, in a paper on human factors in nuclear safety urged that more resources should be devoted to human factors engineering. Human errors were responsible for a wide range of potential system failures.

"Nuclear power stations are examples of large centralised systems in which the implications of human error are far greater than with other systems in the past," he said. "What can we do about human errors?"

Prof. F.R. Farmer, latterly safety adviser to the UKAEA, gave as his opinion that the TMI incident did not result from the failure of an operator on a particular day, but could well have resulted from the failure of a pattern of organisation set up in the 1950s. "The failure was to have put a man in that situation, to correct something which was difficult to correct and which could have been more easily foreseen and corrected if done in the design phase, or on the maintenance floor," he said.

Peter Adams, of the EETPU, said it was pretty well accepted that the development of nuclear power in Britain would depend to some extent on the degree of public acceptance of it. "Do you think that the development is helped or hindered as far as public acceptability is concerned by the development of the PWR in this country, and if it is hindered should we continue to develop it?" he asked.

Prof. Farmer—acknowledging that that was a loaded question—said he believed it was inevitable that there was going to be public discussion about reactor safety, no matter what type of reactor was chosen. "I am anxious that that discussion should be conducted in a way in which we try to encourage understanding on both sides," he said. "I think there should be an understanding between ourselves and other bodies that we should try to have a common language: admitting that there is some risk in carrying out a fairly advanced form of technological development, but it is worthwhile—in fact I believe we have no option. We need energy, and the alternative is worse."

Dr Embrey said it seemed to him that the point about the anti-nuclear movement was that the question was not really about safety of reactors, but about the sort of society one wanted. Quantitative relative risk criteria were not really relevant: the real question was what one regarded as a high "quality of life". "If the pro-nuclear lobby wishes to win 'hearts and minds' it must recognise that this is the ground on which the debate is conducted," he said. "To that extent I think whether one is pro- or anti-nuclear is an open question: it is really a question of how one views technology." Much of the discussion had centred on how one communicated "risk" information to the public: "How *does* one communicate ideas of probabilistic risk assessment to the public at large? When one is talking about the public at large one has to include the decision-makers, because decision-makers are not necessarily engineers or mathematicians; I am surprised more work has not been done in looking at the way people perceive probabilistic information."

Prof. Bryan Harvey, conference chairman, put the cap on the discussion. A lot of people at the conference must be physicists and engineers, he said; might the "despised profession" of sociology have something to teach them about how the problems they had been discussing might be solved? "I suspect that a lot of what we have said is not a problem to the sociologists." □

"It is pertinent to point out that the total amount of activity which remains after a few thousand years of storage is very low compared with the total radioactivity of the natural environment, even for a very large nuclear programme.

"Reserves of workable uranium ores are estimated to amount to no more than 4 million tonnes. Uranium and thorium and their daughters are widely dispersed in the earth's crust, at levels of 1-2 ppm; there is about 4 000 million tonnes of uranium in the oceans, and about 10^{12} tonnes of uranium in the top 1 km of the crust as a whole. Even if all the 4 million te of ores were used in nuclear programmes, the resulting long-lived component of the high-level waste would therefore be a minor addition to the natural radioactivity of the earth (approximately 1/10 000) even if fast reactors were used to achieve the highest efficiency of fuel use. In the very long term, of course, the total radioactivity would be slightly decreased, since nuclear fission results in the formation of shorter-lived isotopes than the original uranium fuel."

Dr W. Heimerl, of Eurochemic, Belgium, presented a state-of-the-art review of the vitrification programmes of European countries – France, the UK, the Fed. Rep. of Germany, Belgium and Italy – recalling at the outset that the first proposal for the vitrification of high-level wastes was made in the United States as early as 1951.

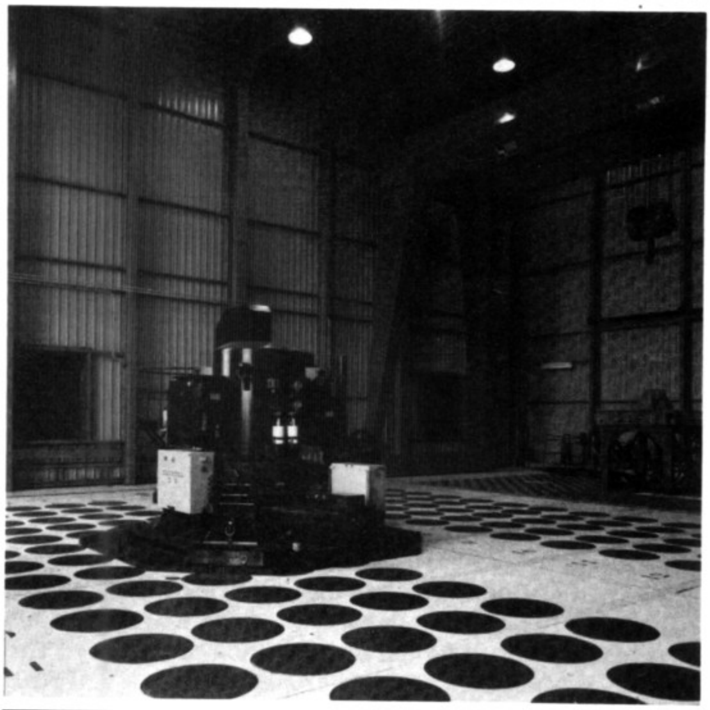
In France, early work on the PIVER process had been followed by the building of the AVM plant at Marcoule [*see*, e.g. ATOM No.269, March 1979 for a review of this and other work in Europe]. Up to April 1980 the AVM plant had vitrified 230 m^3 of fission product solutions with a total activity of about 25 million curies; in total, 108 te of active glass had been produced in 313 canisters, during a running time of 7 500 hours. The next step would be the construction of a vitrification plant at Cap de la Hague, which would have a greater production rate than AVM and should come into operation in 1986. A third plant, the second at Cap de la Hague, was planned for commissioning six to 12 months later. In Britain, considerable work had been done and a full-scale inactive HARVEST development facility was planned at BNFL Windscale. The ultimate objective was the construction of an industrial-scale active vitrification plant at Windscale, which should be operating in about ten years' time. BNFL had been considering the possibility of licensing the French AVM process, but a final decision had not yet been taken.

In Germany, three different processes had been developed: VERA, at Karlsruhe, FIPS at Jülich, and PAMELA, developed by the Gelsenberg Company and Eurochemic. In 1977 it had been decided to focus work on the PAMELA process, as it seemed to have the best chance of leading quickly to a demonstration plant. Meanwhile, DWK – the company having charge of the reprocessing of spent fuel and radioactive waste conditioning in Germany – had chosen the French process as its reference design, this being the only process which was already being tested and demonstrated actively on an industrial scale. An AVM-type plant, to be called HOVA, was to be built at the Karlsruhe reprocessing plant, to come into operation in 1986.

Dr Heimerl said the broad base of vitrification work in Europe "seems to be reasonable and advantageous in this field, which is extremely important for the future of nuclear energy."

Other immobilisation techniques

Dr F.R. Glasser, Reader in Chemistry at the University of Aberdeen, reviewed ceramic and concrete forms which might be used for the immobilisation of high-level wastes, pointing out that the survival of ceramics, minerals and cement-like materials in a wide range of relatively uncontrolled natural environments suggested that they might be durable hosts. Rocks and minerals were known to have survived in essen-



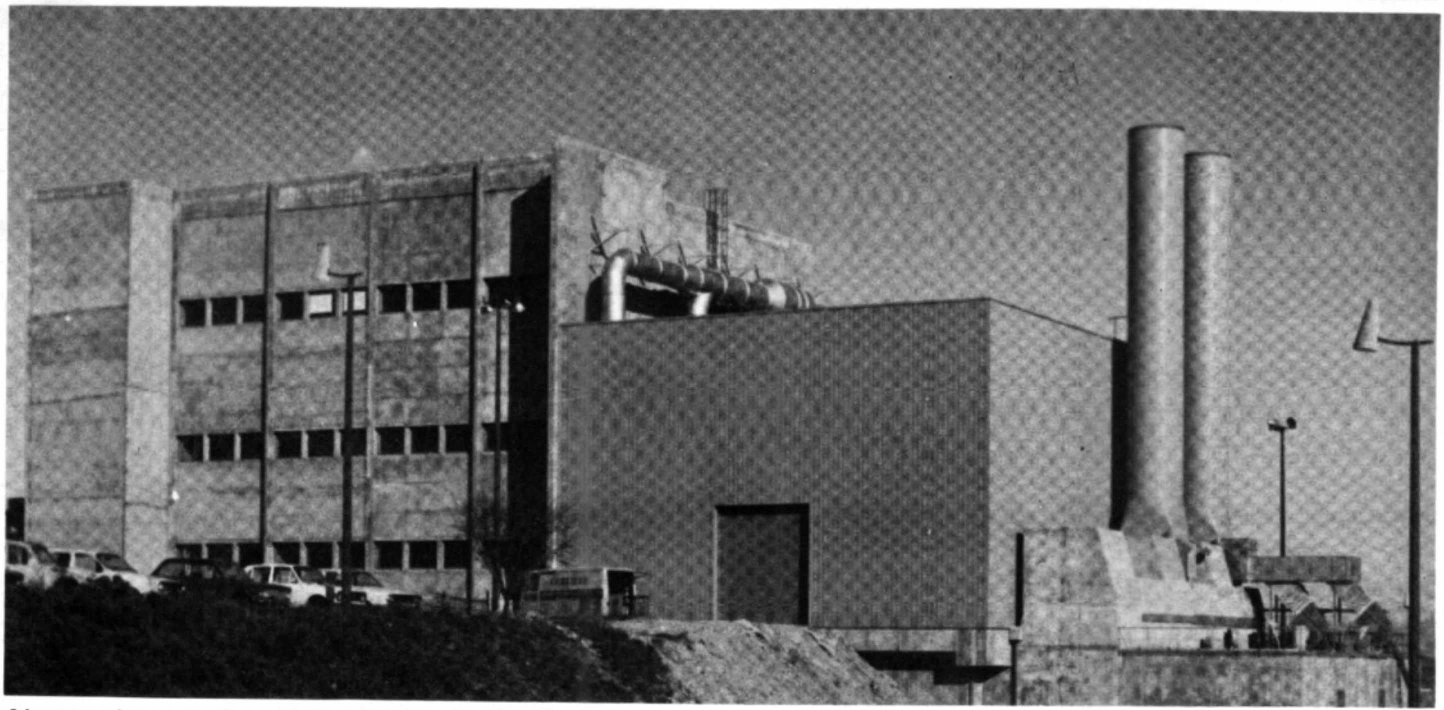
tially unaltered form for $0{\cdot}5-2\times10^9$ years; man-made ceramics had been made for 10 000 years.

"Engineers, administrators and the public want clear-cut solutions to the multiplicity of problems raised by radwaste immobilisation," he said. "Not surprisingly, therefore, the question arises: which is best – ceramics, glass or cement form? It is unfortunately not possible to give definite answers to this deceptively simple question. Firstly, I note that the problems posed by waste immobilisation have, like the wastes themselves, been allowed to accumulate. Research funding – never easy to obtain – has been concentrated primarily on glass-fusion routes for high-level wastes, and we know most about the glass routes. Alternative processes have undergone only piecemeal development, usually on 'shoestring' budgets and without much continuity of funding. Secondly, the field suffers from a lack of international and national coordination as well as a lack of adequately-defined objectives, despite (paradoxically) a surfeit of 'overviews' and 'feasibility studies'. It is not sufficient to require that a radwaste be immobile without also specifying the conditions under which it is expected to remain immobile."

Dr Glasser said it appeared that ceramic and cement forms held much promise, but they required more evaluation. First, however, they had to be got past the initial development stage and secondly appropriate test criteria had to be agreed and tests undertaken for a sufficient length of time to ensure that the results could be extrapolated with reasonable confidence.

Dr A. Gibbs, of Bedford College, University of London, then discussed geological aspects of radioactive waste repositories – pointing to both the very long times for which some geologic structures had been known to be stable, and the very short times in which other formations had altered dramatically.

"Excessive caution by those rightly concerned with the protection of our environment could reduce our chances of being able to choose the safest possible option of long-term waste management," said Dr Gibbs. "Any reduction in the data base at this early stage by ruling out disposal options could result in a less safe option being chosen in the long run. On the other hand, it is important to acknowledge that geology deals in probabilities, not certainties, and that our knowledge of complex natural systems is, and always will be, incomplete and is only gathered by necessarily slow and detailed field and laboratory studies.



Above, the exterior of the *Atelier de Vitrification* at Marcoule (AVM) and (left) the interior of the area in which vitrified waste is stored. Canisters are stacked ten deep in cylindrical "boreholes" formed in a concrete cave, cooled by circulating air.
Cogéma

"Geological research into problems other than that of nuclear waste has already been harassed by worried people in some parts of Britain because of the association that geology now has with nuclear 'dumping'. Geologists, of all groups of scientists, are probably the least prepared for such a role as scientific bogey men, having in general good public relations. It is to be hoped that an increasing flow of information to the public at large will remove some of the fear from, but not the concern for, this issue."

Public acceptance

Lastly, Professor Sir Frederick Warner tackled Dr Gibbs' concluding point, in a paper on public acceptance and social responsibility. Sir Frederick was of course an assessor assisting Mr Justice Parker in his conduct of the inquiry into BNFL's plans for the expansion of the Windscale reprocessing plant, three years ago. Since then, in Austria a referendum had resulted in a decision not to commission a new nuclear power station; in Switzerland a narrow majority had been in favour of continuing while in the Fed. Rep. of Germany the construction of new facilities at Gorleben, including reprocessing, had been held up following public hearings. In the United States nuclear power construction had been held up following the Three Mile Island accident; France continued its major programmes; in Britain the go-ahead had been given for AGR stations at Heysham and Torness and for the study of a new PWR at Sizewell; the work at Windscale on new facilities for fuel storage and reprocessing had begun.

"When one is discussing acceptability and attitudes we have to face the fact that social scientists say we are arguing entirely about the wrong questions, because we are concerned with facts in our discussion, whereas the proper discussion would be about values. We are taking for granted what they call a dominant social paradigm, which assumes we need economic growth and a higher standard of living – as against the alternative viewpoint, that we should abandon growth, go to simpler systems of living, dismantle the central power of the State and proceed to much more localised forms of society based on consent, at a lower level."

Many of the arguments in the controversy over nuclear power in general were far beyond the comprehension of most people, he urged. "It is for the Government and decision-makers to try to assemble facts, and for those of us who are engaged in technical studies to try to put before them what we think are logical reasons for what are essentially political decisions. The decision-makers will be guided in their political decisions by what they think the public will decide to do and what they think will be their chances of being elected in a year or two's time. Their timescale is very short."

The unknown and unfamiliar was likely to attract attention, and to give a great deal of trouble. The central problem faced by the nuclear industry was summed up in what somebody once called "the three books of Genesis" – carcinogenesis, teratogenesis and mutagenesis. For the female half of the population at least these implied mutilation and painful death, birth-damaged babies and a danger to future generations, and the fear of them was fundamental and inescapable. They wanted to know a great deal more about the risk they might be exposed to from a proposed development before they could declare that it was acceptable.

Comparisons between various industries and between the hazards of everyday life could be made; but they were not necessarily helpful. "For scientists, the discharge of their social responsibility does not end with risk assessment and making the figures public," said Sir Frederick in his paper. "It is necessary to find out why large sums of money can be raised to send some identified child for a particular treatment, but not to keep going some health activity which would save many more lives for the same expenditure. It can sometimes be done. In 1967, about two million were estimated to have died of smallpox in the world. By 1980, smallpox had been eradicated finally for a total cost of $300 million, or, at 10 per cent interest on the capital, the cost per life saved is $15.

" – 'but that was in another country'§ – and perhaps the poet knows more about the human mind." □

§Sir Frederick was quoting here from Eliot's borrowing from *The Jew of Malta*: "Thou has committed
Fornication: but that was in another country
And besides, the wench is dead"
which he had used earlier in his paper to illustrate the differences in public reaction to events as diverse as the Flixborough disaster, the deaths of 36 people in a London nightclub in August, the deaths of 250 in the collapse of a stadium at a bullfight in Colombia earlier this year, and the deaths of 15 000 in Gujarat early in 1979 following the collapse of an irrigation dam.

WHITHER THE 'RENEWABLES'?

Although the United Kingdom has access to the largest 'conventional' resources of energy of any country in the European Community, as a trading nation we cannot regard ourselves as isolated from the world scene. The world cannot for much longer rely on oil and natural gas to sustain even modest economic growth, and by about the end of the 1990s depleting reserves of these fuels seem likely to set a limit to the further expansion of their supply. Therefore, to provide for continuing economic growth other sources of energy, and technology for its more effective use, will need to be developed.

Dr J.K. Dawson, Head of the Energy Technology Support Unit at Harwell, surveyed the 'renewable' sources of energy in this paper, which he presented at a conference on *Energy in the Nineties,* sponsored by the Highlands and Islands Development Board and the Royal Society of Edinburgh and held at the Aviemore Centre, in late September.

In examining the part that the renewable sources (solar, geothermal, wind, wave and tidal energy) may play it is necessary to consider very carefully the energy use systems into which they would be incorporated. An important factor is that in the long term it is very likely that the cost of energy to the user will increase in real terms under the combined influence of:

- an increasing cost of recovering the primary fuels
- a shift towards more highly processed secondary fuels such as substitute natural gas, synthetic liquid fuels and electricity for use in applications previously met directly by oil or natural gas.

Whilst the full effect of these factors will probably not be felt until the early years of the 21st century, they may well be having some increasing influence in the 1990s. Their importance is that in planning for the future a major objective must be to alleviate the overall economic impact of the rising energy prices: the problem will not necessarily be a physical shortage of energy but a squeeze on national financial resources to pay for it.

Energy supply already accounts for a significant commitment of the United Kingdom's productive resources: currently our expenditure on energy supply is roughly one-tenth of Gross Domestic Product and it could well rise further. A major aim for energy research and development must be to provide ways of satisfying the growth in users' needs whilst containing the effect of increased energy costs. Great importance attaches, therefore, to the criterion of cost-effectiveness in the particular user market at which a renewable source would be aimed.

Most of the finance for the UK's research and development programmes on the renewable sources comes from the Department of Energy (some other funding is provided by industry and by other Government Departments), and the general aims of the programmes are:

- to establish whether or not there are viable technical options
- to determine whether they could compete economically in the appropriate user markets
- thereby to provide a firm factual base on which commercial exploitation could occur in the favourable cases and assessments can be made with some certainty about their contribution to energy supply and thereby what part they could play in overall energy policy.

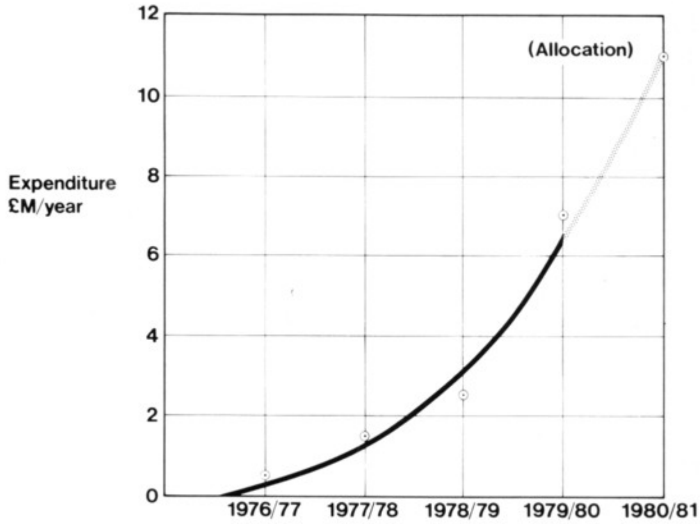


Fig. 1 Department of Energy expenditure for R & D on renewable energy sources

The present state of knowledge

The R & D programmes have been running for three or four years with expenditure rising each year as the work has begun to move out of desk assessment studies into laboratory work and in some cases to field trials and full scale exploratory work (Fig. 1). They have led towards a much clearer understanding of the role of the renewable sources, but considerable further work is needed to reduce the uncertainties. In this paper I will not be able to describe the programmes or their results in detail, but I will illustrate the broad trends. In order to do that I will start from the point of view of how we use energy.

Figure 2 illustrates one simple way of analysing the forms in which energy is delivered, and I have indicated in it the most likely applications of the renewable sources.

Low Grade Heat Over a third of the total energy use is for providing low grade heat—mainly for keeping us warm at home and at work. The two most relevant renewable sources are solar and geothermal energy. From the economic point of view it is the overall system which must be evaluated. The system costs must include back-up supplies and equipment where needed (e.g. for prolonged sun-less periods or the use of electricity for water heating in summer by householders who rely mainly on coal) and maintenance over the life of the equipment. As an example, a way of expressing the results for various methods of heating a typical 3-bedroom semi-detached house conforming to 1979 standards of insulation is

Delivered energy Breakdown of use in the UK in mid '70s	Most appropriate renewable source for UK conditions — Medium Term	Long Term
8% Non-energy		
24% Transport		Biofuels
8% Electricity	Tides, Wind	Waves, Geothermal?
21% Heat > 120°C	Biofuels & organic wastes	
39% Heat < 120°C	Passive Solar Geothermal aquifers Solar water heating	Active solar space heating

Fig. 2 Relationships between the renewable sources and the form in which energy is delivered

shown in Figure 3. The annual system cost is the sum of the x and y coordinates at any point and all points on a 45° diagonal will have the same total annual system cost: the nearer the diagonal is to the origin, the cheaper the system cost.

If we now take solar heating, our current best guesses of the system costs for the same type of house are shown for comparison in Figure 4. Some types of 'passive' solar heating look promising compared with the band representing the conventional fuels from Figure 3, but 'active' solar heating is more expensive. This enables us to devise field trials to confirm the results for passive heating and to derive a target at which to aim the further research on active heating.

In solar heating we are at the stage of supporting a considerable number of field trials not only in order to gain technical information which can be used to define better systems but also on how people react to them and use them. It is in this technical area above all that progress in exploiting the renewable sources will depend upon the decisions of individual householders, architects or builders rather than upon major central Government decisions, and we need much more information on how individuals and small groups of people adapt to new technical ideas which may well influence their lifestyles. One of the field trials is of a system for providing hot water in a students' hostel at Kirkcaldy, constructed for Fife Regional Council and monitored by Napier College, Edinburgh.

Despite its northerly position, it is possible that solar heating may be developed to a commercial state in Scotland. Indeed it is at the same latitude as southern Sweden where considerable efforts are in progress to harness solar energy for heating water and buildings. One of the Department of Energy's contractors, who has developed and is testing a solar space heating system in several houses at Milton Keynes has also built trial homes in Edinburgh in collaboration with a Scottish building firm. Annual solar radiation levels are about 15 per cent lower in Scotland than the average for southern England, but the heating season is longer and there is a greater demand for heat in the Spring and Autumn when better advantage can be taken of the solar radiation than in the depth of winter.

The technical potential of solar heating for the United Kingdom as a whole is at least 50 mtce/year. What fraction of that can be exploited in reality will depend in substantial measure upon the degree of success in the development programme and the field trials on reducing the costs.

The supply of heat from geothermal aquifers located at depths to about 3 km may be subject to limitations and criteria other than economic ones. The technology has already been developed elsewhere and there are a growing number of schemes around Paris for heating apartment blocks at a cost which is said to be competitive with oil-firing. But the question we have to resolve is: do we have a resource and what is its distribution? Early geological investigations have focused attention on the sedimentary basins of the South and East Coasts of England, and Northern Ireland. The carboniferous area known as the Midland Valley of Scotland may be worthy of detailed exploration, but it has a complex geology and it is already apparent that even if potential

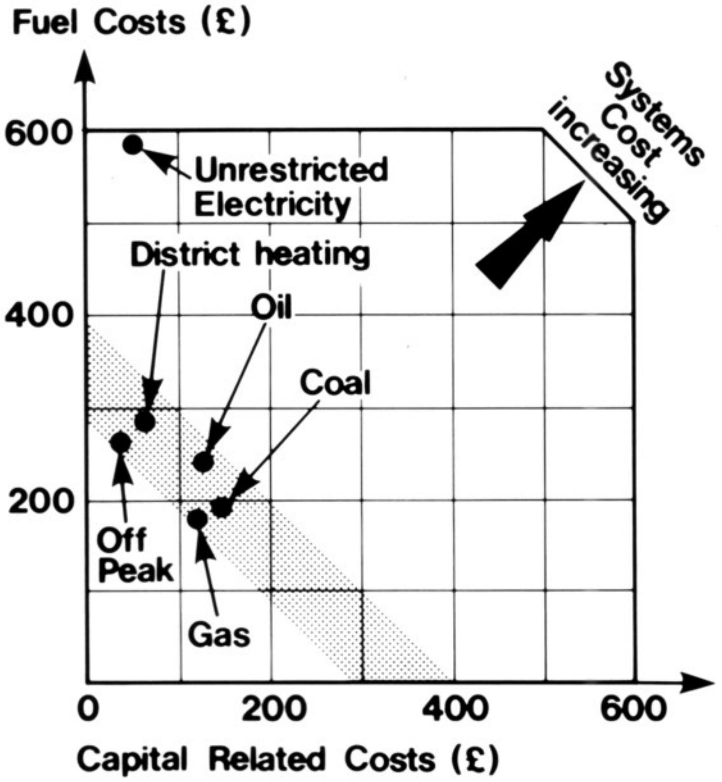


Fig. 3 Space and water heating in 1979

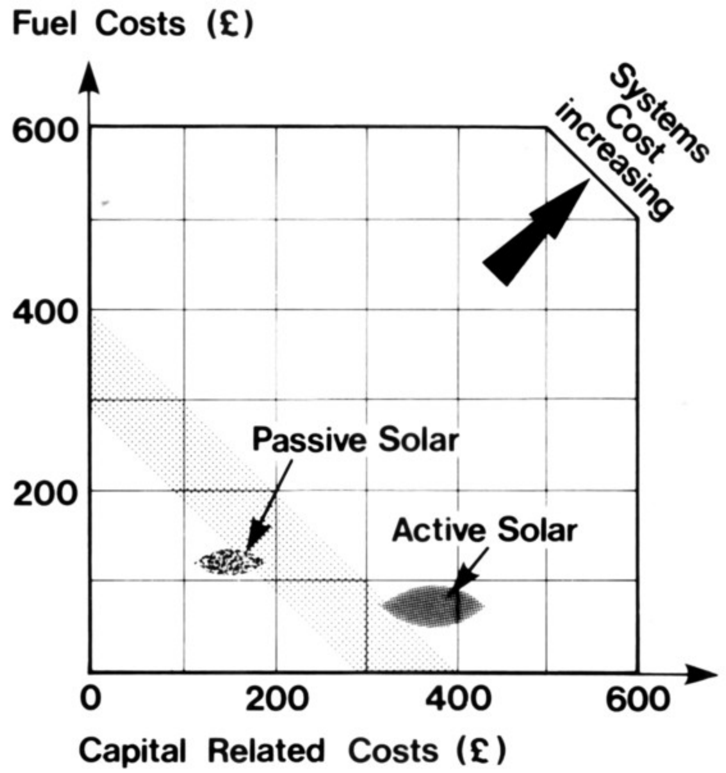


Fig. 4 Space and water heating based on renewables in 1979

geothermal resources were confirmed here their exploitation would be difficult, and more costly and speculative than in the other basins. The first exploratory borehole has been drilled at Marchwood, on the outskirts of Southampton, and water at 70°C was confirmed at a depth of 1 600m. So at least in one basin we believe we have a resource. It remains to be demonstrated that the warm water can be exploited in a suitable market for the heat – maybe a shopping complex, civic centre, a substantial horticultural project or an area of high housing density such as blocks of flats. These possibilities are being examined.

Electricity The renewable sources most technically appropriate for providing a contribution to the United Kingdom's electricity supply are wind, wave, tidal and geothermal energy. The first three of these share one very important feature in common: the supply is intermittent (though for tidal energy the variations can be predicted in advance).

We have been making good progress in establishing their technical feasibility. For instance:

- on wind energy one industrial consortium has recently completed the design of a large wind-driven generator of rated capacity 3·7 MW and the Department is considering whether a prototype unit should now be built; a second consortium is producing a design study of a new type of machine with vertical axis configuration which may offer cost advantages, initially with a capacity of 130 kW, based on an invention by Dr Musgrove at Reading University; and Sir Henry Lawson-Tancred has built and is operating a 100 kW machine in Yorkshire.
- on wave energy, open water trials at tenth-scale of two designs of wave power machines have been carried out, and larger scale work under an IEA collaboration in the Sea of Japan has been completed; together with a range of further design studies these have pointed the way to more efficient designs. [See box.]
- on tidal energy, studies carried out for the Department's Severn Barrage Committee have confirmed that building an electricity-producing barrage across the Severn Estuary would be technically feasible.

However, as noted earlier, the adoption of these technologies will depend to a considerable extent on the estimated costs of the power which they would produce. We have been putting considerable thought in collaboration with the Generating Boards into solving the problem of how best to evaluate the output, bearing in mind its variability.

If these sources are to make a significant contribution to the UK supply then we have to consider their connection to the mainland grid distribution system. (The value of a wind-driven electricity generator to an isolated local community, of which there are many in the Highlands and Islands region, may be quite high but in national terms the contribution will be low.) At any time, the value of a flow of power from a given renewable source will be realised as the savings that the Generating Board makes by reducing output from the lowest merit-order (i.e. highest running cost) plant it has on stream at the time. Whilst a definitive answer to these quite complex system considerations is not yet available, the general indication on wind energy is that such a cost/benefit analysis is now more favourable than was the case three years ago when as a result of much scantier knowledge we concluded in Energy Paper 21 that "although aerogenerators might be economic on certain hill sites if series manufacturing costs could be held down at relatively low levels of production, a clear economic case cannot be made for a programme large enough to make a significant contribution . . . ."

But here we come up against another possible difficulty. Of crucial importance to the economic calculations is the mean annual wind speed at the chosen sites: energy density in the wind depends upon the cube of the wind speed. As wind approaches hilly or mountainous terrain the speed increases, sometimes by as much as 50 per cent as the air flow passes the summit. So the tops of hills and mountains have a very considerable economic advantage for siting the generators, and there are many of these in Scotland. We believe there are many of these in Scotland. We believe there may be some 2 000 such sites in Western Scotland. But in general they are in areas of considerable natural beauty and environmental considerations could become very important.

The CEGB has announced recently that technical progress in various parts of the world is such that sites with lower wind speeds on flatter inland areas may also be worthy of consideration. Such sites could have a lower environmental impact.

Another possible way round the problem might be to site arrays of large wind-driven generators in shallow coastal waters. Whilst this would reduce the overall environmental impact, it would inevitably increase the cost. The technical and economic aspects are being evaluated further.

If wave power is to make a significant contribution to electricity supply, many converters would have to be sited off the western coasts of the Outer Hebrides. A combination of the large size of the converters needed to recover the rather diffuse energy in the waves with the need to ensure the utmost ruggedness to withstand the worst North Atlantic storms led to a prediction of very high power costs (20-50 p/kWh) when first generation designs were evaluated in 1978 by the consulting engineers to the programme. That evaluation highlighted the main problem areas to be attacked in order to reduce the costs. Good progress was made in 1979, but a design has not yet been achieved on which the Department could go forward to the stage of constructing a prototype with a reasonable prediction that economic power could be obtained in a commercial station.

I mentioned geothermal energy as a means of producing electricity. This would be by a different technique from that used for the aquifer sources. An idea still in the research phase is based on the possibility of recovering heat from deep-seated granite masses, at a temperature which would be attractive for electricity generation. It has been shown to work technically in a pioneering experiment in the USA, and the United Kingdom has its own research project in Cornwall to which the Department of Energy has allocated recently some £6 million. For geological reasons, the most attractive locations (producing the most favourable economics) are in Cornwall, but in due course the technology might be of interest in some of the granitic areas of Scotland. However, I do not think that exploitation could begin there as early as the 1990s: there is much work still to do to prove both the technology and the economics.

Liquid Fuels Growing plants and trees are collectors of solar energy, and, in effect, store that energy within their structure. It can become available to us either from the plants or indirectly from the processing of a wide variety of organic wastes (for instance domestic refuse and the wastes from intensive animal farming). We have a research and development programme on many of these possibilities, for recovering the energy as heat (i.e. by combustion in boilers), or as gaseous or liquid fuels. Figure 2 showed that about one quarter of our total delivered energy is used for transportation, mainly in the form of liquid fuels. In principle the organic biomass sources may be able to contribute to the liquid fuel supply, but our present judgment is that the contribution would not emerge until after the 1990s and will, in any case, be very dependent upon reducing the costs. The technically realisable potential might be up to 2 mtce/year by fermentation processes and perhaps up to 15 mtce/year by thermal processing but fermentation costs appear to be too high to be of interest in the UK and present estimates of the costs of liquid fuels by thermal processing range from somewhat lower than that of oil to twice as high – that is, there are considerable uncertainties. Thermal processing is of particular significance in the Scottish context as it could include the treatment of some forest wastes and the production of fast-growing species of trees on marginal farmland. Fast growth and high yield would be more important than quality – trees such as poplar, willow, elder, southern beech or eucalyptus grown on, say, a 10 year rotation might be suitable and might offer the farmer an income on a timescale more in keeping with that of normal upland farming than the 40-60 years rotation of forestry for producing furniture and building materials. Further assessments are needed before we can be sure whether or not these possibilities can become realities. In Scotland, technical contributions to the programme are being made by the Rowett Research Institute, the Institute of Terrestrial Ecology, the Forestry Department of Aberdeen University and the Forestry Commission.

Conclusion

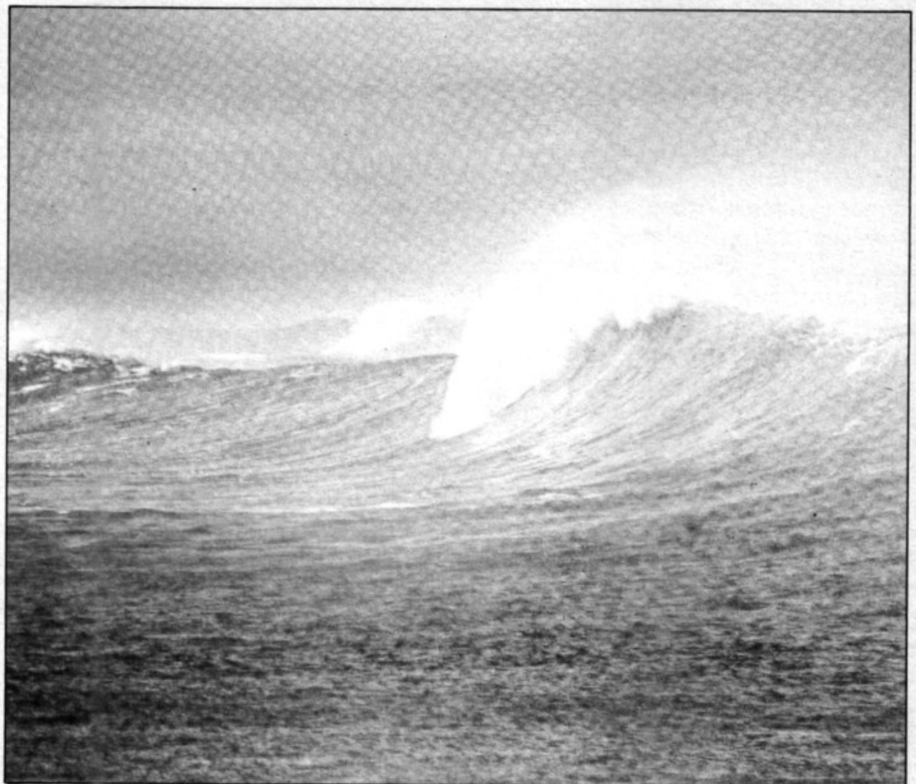
In this brief survey I have been able to do little more than provide a much simplified view of how the Department of Energy's on-going research and development programmes are shaping the thinking about the contribution of the role which the renewable sources may play in the UK's energy supply. I should stress that the views I have given do not necessarily commit the Department to any particular future course of action: the overall policy will be determined in the light of the further results and experience as they emerge.

The renewable sources represent a disparate group of technologies: some are at a preliminary research stage whereas others are already reaching commercial exploitation but may require full-scale demonstration. It is difficult, therefore, to make generalised statements about them. However, whilst our present judgment of the total *technical* potential which they might offer ultimately in the long term is substantial (perhaps up to around 200 mtce/year), the fraction which can be realised will depend upon many factors which include institutional, social, environmental and economic considerations. Rather than dwell on the technical aspects, I have chosen to highlight the importance of system economics in how we evaluate our progress and in setting targets for future R & D: we must relate our growing knowledge to the real commercial world. In terms of the theme of this conference – the 1990s – the renewable sources might by then be contributing up to about 10 mtce/year, but with a possibility for this to increase at a later stage if all goes well. □

Wave power

The Government has announced recently increased funding for wave power research projects and Mr John Moore, minister with responsibility for renewable energy, has opened an advanced test tank that should greatly facilitate wave energy studies.

The Department of Energy initiated its wave energy research and development programme in 1976 with a £1 million feasibility study that was to last two years. Progress was good and funding was increased to £2·5 million in 1977 and a further £2·9 million was allocated a year later. In September this year approval was given for contracts in excess of £650 000 to be placed for research and it was announced that the annual budget for the wave power programme would be increased.



Waves are of course caused by the action of winds blowing over the sea. As the strength of the wind and the uninterrupted distance over which it can travel increase, so does the amount of power in the waves. The UK lies in a main wind belt and the Atlantic is a large body of water. In the region off the Outer Hebrides, considered a very suitable location for the tapping of wave energy, it is estimated that wave power is approximately 50 kW per metre, and that the potential for delivery to the grid as electricity is about 8 kW/m. An attractive feature of wave power is that the waves are largest, and therefore contain most energy, during the winter when demand for electricity is at its highest.

Converting wave power to electricity for the grid however presents many problems. In theory many systems could be made to extract some of the energy, but it is not easy to overcome the technological problems in doing so and to achieve efficient and economic conversion. Results are encouraging however: early designs have progressed from laboratory experiments to field trials and new systems have appeared. The mainstream research and development centres on wave energy conversion but related research, into for example environmental effects and shipping hazards, also plays an important part. [See, for example, ATOM No. 273, July 1979, pp 181-186, *The 'Renewables' and the Environment.*]

The advanced wave power test tank opened by Mr Moore in September, at the premises of Wavepower Ltd near Southampton, is the second of its type in the world, with the facility of being able to produce printouts and limited analysis of data from experiments on wave energy machines in seconds, using sophisticated microelectronics.

The emphasis in research is shifting. Wave energy research is becoming less costly, with the Government now aiming to assess all the ideas and choose the best for development. The aim is to single out the most promising features of all *(over)* concepts and combine them to produce the most efficient and the cheapest electricity production system. At the start of the research programme four designs were selected: oscillating vanes, wave contouring rafts, rectifiers and oscillating water columns. Later other systems were also studied—submerged ducts, flexible bags, oscillating cylinders and free-standing vertical plates. The present programme is concentrating mainly on the study of oscillating water columns, flexible bags and oscillating cylinders with some additional work aimed at proving the viability of power take-off systems for the oscillating vane devices: commonly referred to as 'nodding ducks', designed by Stephen Salter of Edinburgh University. Conceptually, the 'nodding duck' converter is a long cylindrical spine along which a series of tear-shapes vanes are positioned. Waves cause these to oscillate about the spine, and it is this motion which could be harnessed to generate power. The energy the 'ducks' can absorb is maximised by the shape of the front (i.e. wave-facing) surface; the rear surface is cylindrical, so that no waves are regenerated by it. A team from Lanchester Polytechnic have carried out one-tenth scale tests on Loch Ness and Edinburgh University researchers have done one hundredth scale laboratory tests.

Conceptually, the wave-contouring raft consists of a series of hinged, shallow pontoons moored in line, normal to the principal wave direction. The pontoons vary in size, the first being smaller, and the relative angular movement of adjacent pontoons resulting from wave action could be used to generate power. Wavepower Ltd of Southampton were developing the raft, and tested a tenth-scale prototype in the Solent. Tenth-scale tests are of course at a thousandth full-scale power.

The cost of electricity generated by wave-power devices will of course be an important factor. In 1978 estimates were that electricity might be produced for 20 p/kWh for the 'ducks' and about 30 p/kWh for the raft. The estimated range for a simplified steel sheet version of the raft, if made in large numbers, now stands at 5-15 p/kWh. Lanchester Polytechnic's tests on the 'ducks' showed that a device up to 10 m high and 300 m long was practicable but that engineering problems were many and the cost was high. The tests did show however that the basic idea of a spine and a hinged combination of surfaces was sound.

A third device—the 'clam'—consists of a series of flaps hinged from the front of a floating rectangular spine. Between each flap and the spine is an air bag feeding into the hollow spine via a turbine: wave action closes and opens the flaps thus driving air from the bags through the turbines. Air pressure in the spine allows the bags to inflate again between waves. The turbines are designed to operate continuously with air flow in both directions. Work on the 'clam' has been done by a team from Sea Energy Associates, based at Lanchester Polytechnic; the aim was to modify the early concept of the spine to simplify construction, improve power take-off and thereby reduce costs. Sea Energy Associates said ten 'clams' mounted on a 300 m spine could generate 10 MW at a delivered cost in the region of 6 p/kWh.

Another approach to wave energy conversion is to use the piston action of waves to create an air flow through turbines. Examples include several types of oscillating water column being designed by the National Engineering Laboratory, Vickers Engineering Ltd and Queens University Belfast. An oscillating water column is a bottomless device with a hole in the top surface. As waves enter the water level in the column oscillates thus forcing air through the hole at the top. Work at NEL has aimed at increasing efficiency by altering the shape of the column and developing the turbine and its associated air flow valve system. The design currently favoured at NEL is a device fixed to the sea bed with few moving parts, which might generate power at an estimated 5-15 p/kWh. Other designs of OWC being investigated are a submerged device (Vickers) and a point absorber (Queens University).

Then again, flexible air-filled bags might be attached to a semi-submerged hull lying head-on to the sea. In principle the hull contains high and low-pressure ducts; wave crests collapse the bags and the displaced air enters a high-pressure duct and operates the turbine. In wave troughs the bags are refilled with air via the low-pressure ducts. Research into this concept is being carried out at Lancaster University by a team led by Prof. Michael French, and by Wavepower Ltd.

The oscillating cylinder system relies on the principle that a submerged cylinder rotating eccentrically will turn in response to wave action, giving rise to forces in mooring cables. These forces could be used to work seabed pumps using either sea water in once-through systems, or fresh water in recirculatory systems, to drive water turbines and generators. Research into this concept is now being undertaken by Sir Robert McAlpine and Sons Ltd.

There are many other design concepts. The consequences of wave power stations in terms of environmental impact and effects on local communities would need to be evaluated for detailed designs and specific locations. The Department of Energy's Wave Energy Steering Committee has however undertaken some preliminary investigations. Attention has been directed toward the Outer Hebridean region as this is the most favoured location. Among the considerations for study are:

- the effect of a line of converters on wave climate and on the shoreline—e.g. erosion and accretion rates;
- the consequences of residual drift currents that converters might produce in terms of the behaviour and survival of fish;
- the hazards to shipping which might be created by converters, and changes in sea state which might be caused by interference between incident and reflected waves;
- and the potential impact of wave energy converters on economic and social development onshore: areas which might be affected are often characterised by declining populations and high unemployment. The building, operation and maintenance of wave energy converters would need a local labour force; and some of the electricity generated might be used to power new industry.

It may be many years before wave power could be generated commercially, but current research and development work is encouraging. Estimated production costs are still high, but they are decreasing. The costs of electricity from power stations now being built in Britain are in the range 2-3 p/kWh for nuclear, 3-4 p/kWh for coal-fired and 6-8 p/kWh for oil-fired plant, compared with current estimates of 5-15 p/kWh for wave energy. There is therefore still a long way to go. If wave energy and other renewable sources are to be developed partly as an insurance policy, however, then cost will not be the sole determining factor.

Lynne Beynon

BOOK REVIEWS

More questions than answers?

The Fast Breeder Reactor—Need? Cost? Risk? Edited by Colin Sweet; *Macmillan, 1980; 232 pp, indexed; £20. ISBN 0 333 27973 5.*

This book is made up of 15 of the contributions to a two-day conference held at the South Bank Polytechnic in November 1978 at which, as the editor and conference convenor himself says, there was "no question of trying to strike a balanced view". The names of many of the authors and their themes will be well known to those who have followed the nuclear debate in the United Kingdom during and since the Windscale Inquiry. Only three of the 17 conference contributors were drawn from the nuclear industry itself and their invited papers were confined to specific technical or economic aspects. The general policy and political aspects are dealt with entirely by speakers from outside and it is to be regretted that the conference organisers' original intent to publish the discussion sessions ran into difficulty: the result would have been of much greater value. The book provides an indication of some of the issues raised in the nuclear debate though for completeness it should be read in parallel with other publications, such as *Nuclear Power and the Energy Future,* the proceedings of the Royal Institution Forum held in October 1977[1], and our own analysis of the IIED study[8].

Most of the contributions are concerned with matters that have received a good airing over recent years, not least in the pages of ATOM, where papers have appeared on the question of the role of fast reactors by Marshall[2] and Nicholson and Farmer[3]; safety by Marshall[2] and Cobb and Smith[11]; risk analysis by Fremlin[6] and Farmer[7]; radiation effects by Sagan[9] and in the US BEIR report on effects of low-level radiation[10]; and weapons proliferation aspects by Sir John Hill[4] and Marshall[2, 5].

It is to be regretted that the editor has added a lengthy introduction that was not subject to discussion at the conference and which contains several misleading statements. One example will suffice. In an appeal for more information he suggests that a "partial core melt" in a Chapelcross reactor was concealed for 15 years, yet paragraph 82 of the Report and Accounts of the UKAEA for the year ended March 1968 (published by HMSO) reported that "after nearly eleven years of successful operation of Calder type reactors the first major set-back occurred on 11th May 1967 when experimental fuel in one channel of Chapelcross reactor No. 2 melted. The reactor was shut down immediately, and there was no hazard to the general public or to operating personnel." The report goes on to discuss the causes and remedies. The incident was mentioned in two subsequent Annual Reports including the successful recommencement of operation in 1969. A little research could have avoided this and the other errors, at least one of which was brought to attention some time ago[12].

Dr P.M.S. Jones
Head of Economics and Programmes

1. *Nuclear Power and the Energy Future,* a Royal Institution Forum sponsored by the UKAEA and Electricity Council, NPC, FoE, National Council for Civil Liberties, Conservation Society and Council for the Protection of Rural England: papers published by Symposium Press, London, 1978; edited proceedings published as *Nuclear or Not?,* Heinemann, London, 1978.
2. W. Marshall, *Fast Reactors,* ATOM No. 287, September 1980, p. 222.
3. R.L.R. Nicholson and A.A. Farmer, *The Fast Reactor and Energy Supply,* ATOM No. 277, p. 293.
4. Sir John Hill, *The Driving Forces of Proliferation,* ATOM No. 274, August 1979, p. 198.
5. W. Marshall, *Proliferation and the Recycling of Plutonium,* ATOM No. 263, September 1978, p. 234; *The Use of Plutonium,* ATOM No. 282, April 1980, p. 88.
6. J. Fremlin, *Risk Relativities,* ATOM No. 283, May 1980, p. 128.
7. F.R. Farmer, *What is Risk,* ATOM No. 282, April 1980, p. 108.
8. G.V. Day, H.H. Inston, F.K. Main, *An analysis of the low energy strategy for the United Kingdom as proposed by the IIED,* UKAEA Energy Discussion paper No. 1, May 1980.
9. L. Sagan, *Radiation and Human Health,* ATOM No. 279, January 1980, p. 2.
10. *The report of the US National Academy of Sciences Committee on the Biological Effects of Radiation,* BEIR III; discussed in ATOM No. 288, October 1980, p. 268.
11. E.C. Cobb and R.D. Smith, reported in *The Breeder Reactor and Europe,* ATOM No. 278, December 1979, p. 322.
12. P.M.S. Jones, Letter, *The Ecologist,* Oct./Nov. 1979, p. 256, responding to a report by C. Sweet, *The Ecologist,* May/June 1979; see too p. 179 of *The Fast Breeder Reactor,* here reviewed.

The Necessity for Nuclear Power

By Geoffrey Greenhalgh; *Graham and Trotman Ltd, London, 1980; 260 pp; £16.* * *ISBN 0 860 10 201 7.*

This interesting and unashamedly pro-nuclear book provides a good review of the general economic, environmental and resource case for nuclear power. It leaves aside the technological aspects and concentrates on those that are central to the "nuclear debate". Its easy style and avoidance of jargon will be welcomed by the non-specialist reader whilst those who, like the reviewer, participate in public presentations on energy will find some of the background material collected by Geoffrey Greenhalgh a valuable addition to their armoury.

In his opening chapter the author describes the need for energy, particularly in the third world, and the relationship between energy and economic activity and social welfare. It was good to see the early stress laid on the role of adequate energy supplies in the release of constraints on economic activity. The direction of causality which receives the greatest attention—economic activity leading to energy demand—can obscure the risks of planning oneself into energy constrained growth. It is salutary to reflect on the difficulties the US in particular have suffered in trying to contain their energy consumption and to be reminded of the objectives of "Project Independence". It is also useful to note the relationship, based on World Bank statistics, between social welfare and Gross Domestic Product. The latter is generally recognised as an inadequate measure of welfare, particularly for examining small changes, nevertheless it serves as a reasonable indirect measure and reflects the level of resource available to the nation or individual which can be allocated to material or social objectives as desired.

There are some weaknesses in Greenhalgh's presentation in Chapter 1. He does not distinguish adequately between the energy / GDP ratio and income elasticity (the ratio of growth rates) and he fails to point out the importance of climate, the structure of the economy and the divergence between purchasing power and nominal exchange rates in intercountry comparisons. His conclusions are correct and would be strengthened if these points were brought out clearly.

A good review of energy demand forecasts to 2000 is presented in Chapter 2, drawing on the World

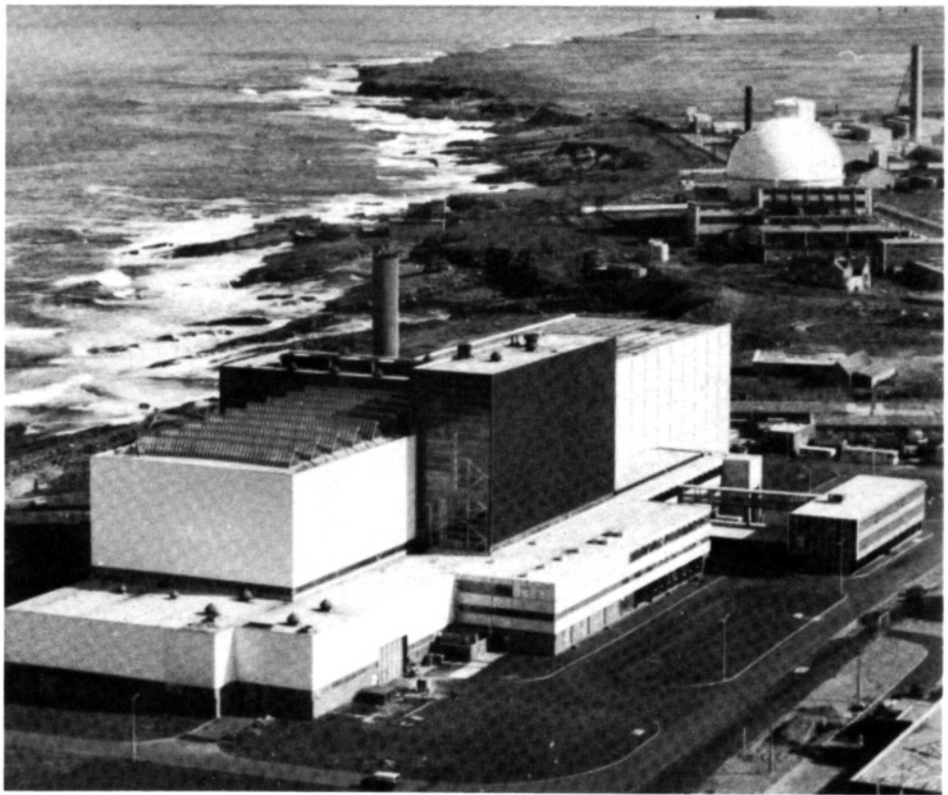
* Available by post from the publishers, Graham and Trotman, Bond Street House, 14 Clifford Street, London W1X 1RD, for £17·50 (surface mail) or £21 (airmail).

Energy Conference, the Workshop on Alternative Energy Strategies, the OECD Interfutures Study, and work at the International Institute for Applied Systems Analysis. The general view is that the world will clearly need as much energy from all sources as it get comes through clearly. The WEC conclusion that "we are now more short of time than of energy" is reinforced and echoes the repeated warnings of the Paris-based International Energy Agency.

Chapters on oil and coal review their potential contribution to energy needs and stress the dangers of over-optimism. These are followed by a good and surprisingly up-to-date picture of the nuclear scene worldwide. The author and publishers have done an excellent job in this respect in a field which has been changing rapidly. Reactors in operation or on order are listed, with the nuclear contribution to electricity supplies by country and region. This includes the centrally planned economies and individual sections on the nuclear industry and programmes of some major third world countries. The nuclear chapter includes comment on fast reactor potential and safety and its current stage of development. (The purist will be concerned by the use of "reserves" and "resources" as synonyms, particularly in the use of the term "speculative reserves", but the thought is correct.)

The succeeding chapter on the future level of nuclear installed capacity draws heavily on recent projections, including those of the International Nuclear Fuel Cycle Evaluation, whose reports were published earlier this year. The INFCE projections to 2000 were based on national returns to questionnaires and continuing economic pessimism has led to a significant reduction in figures returned to a current OECD Nuclear Energy Agency study, particularly by the USA. Some of this may represent over-reaction to the economic climate and institutional difficulties faced by the industry in the recent past. Greenhalgh presents a reasoned and optimistic view of what could be achieved by the world nuclear industry given governmental commitment.

There is little in the book on the comparative economics of energy systems and the cost comparisons rely on US figures, which are not directly appropriate for the UK. In view of the rapid pace of inflation and the complexities of the assumptions and calculational methods this omission may be wise. The most up-to-date picture on comparative costs in the UK is given in the Annex to the recent CEGB Annual Report (for 1980). CEGB and



The PFR at Dounreay and (right) a "fission reactor" which does *not* produce plutonium?

AEA figures support the general claim made by Greenhalgh for nuclear's comparative advantage. [And see ATOM No. 288, October 1980, pp. 271-272.]

Brief though useful sections follow dealing with the possible contribution of nuclear sources to meeting energy needs. The possibilities of substituting for oil in transport; the provision of low and high temperature heat and the use of hydrogen as an energy vector are covered. Some of these possibilities are necessarily well beyond the turn of the century. Nevertheless the deployment of dedicated heat-producing reactors has already started in the USSR and significant developments in the non-electrical uses of nuclear energy can be foreseen.

The chapters of the book dealing with comparative hazards of energy sources contain a useful summary of the literature sources covering accidents and environmental effects. These are set in perspective against accidents and risks in other industries and substantiate the claimed advantages of the nuclear option. It is interesting to note, for example, that catastrophic dam failures have occurred at an average rate of one every two years for 20 years, with a total loss of life averaging some 400 a year—yet dams are regarded as benign by some who call for abandonment of nuclear power, where accidents at civil stations have been few and have resulted in no injury to the public.

There are further chapters on the Three Mile Island incident, including a summary of the Kemeny Commission findings, on radioactive waste disposal and on nuclear safeguards and proliferation. The conclusions of the INFCE studies are summarised and in this the book may prove useful to those who have been unable to get access to the full IAEA publications. The references to the possible role of International Plutonium Storage reflect the original concept as a storage scheme for excess plutonium, rather than current views which tend to stress it as an extension of international safeguards and embracing all facets of civil plutonium production, storage and use.

The final chapter deals with the opposition to nuclear power and analyses its underlying bases. Here the author's views are held and put strongly, with quotations illustrating both the inevitability of the opposition and the extreme position adopted by some of its most strident members. He draws telling analogy with the fears associated with the introduction of railways, again quoting contemporary sources.

There have been too few books over recent years which have sought to explain for the non-specialist the arguments in favour of nuclear power. The media tends to single out particularly newsworthy facets at the expense of the overall argument. Geoffrey Greenhalgh and his publishers have done a valuable job in producing this topical and up-to-date work which attempts to redress the balance.

Dr P.M.S. Jones

Energy Options

Energy Options: Real Economics and the Solar-Hydrogen System, by Prof. J.O'M. Bockris; *Taylor and Francis Ltd, London 1980; 441 pp. indexed; £15. ISBN 0 85066 204 4.*

If I can I like in a review to say something nice about a book. This, from the respected stable of Taylor and Francis and by the redoubtable Professor John O'M. Bockris, covers a very great deal of ground.

Bockris' affiliation is with the Flinders University of South Australia, and with the Texas A & M University in the US. Much of the discussion of energy options in the book is therefore understandably relevant principally to the US case, but the author has set out to deal with the *world's* future need for energy and how this might be met. He argues strongly for the adoption of hydrogen as a "transmission, storage and distribution medium," the hydrogen being produced by the electrolysis of water and the electricity required for this coming from a solar source. As the jacket notes have it, "the coal-nuclear policy, which is the basis of the present energy thrust in research and in financing, is incompatible with environmental and health considerations. However, the alternatives are not those of having nuclear energy or having gross unemployment, but rather those of having nuclear energy or solar energy on a massive scale by means of collection in desert areas. Solar energy is not primarily a source for rooftops *(sic)* or water heating, but one which could supply factories, industries, commerce and transportation."

One should never judge a book by its cover; and the last eight chapters of this one – in which Bockris deals with the practicalities of solar energy conversion to electricity and hydrogen, the relative merits of hydrogen and other fuels, and so on – certainly deal in depth with pretty well every question one could ask about how a "hydrogen economy" might work. There is so much detail given that the book is almost a compendium of "everything you wanted to know but were afraid to ask"; each chapter ends with a summary and for those who don't really want to be bothered with reading the whole thing, or even the summaries alone, the "author's choice of single most important point emerging from chapter" *(sic)*, "more important conclusions" and the like. At the end, for those who have still missed the point, he goes so far as to encapsulate the "three most important conclusions" from the whole work; and there follow no fewer than eight appendices in which the arguments are re-stated.

Despite all this effort, I am sorry to say that because the treatment of the nuclear issue is so awkwardly handled I have little faith in what I read in the rest of the book. A few short examples will serve to make the point. The chapter on fission opens with a potted explanation of "how reactors work". It is wrong. The author is also wrong in his statement of the case for the "breeder": "There is merit in attempting to remain with *fission rather than breeders,* because the fission reactor has the advantage that, although it involves dangers . . . it does *not* involve the production of plutonium. It is the storage of the plutonium wastes which is the quintessential difficulty of the breeder, and this would be avoided by staying with the fission reactor." Confusingly I am sure to those who have stayed with his argument, Bokris goes on to say that "the breeder *is* a fission reactor but, because of a different disposition of the cadmium-absorbing rods which are inserted to modify the chain reaction occurring among the U-235, the neutrons are used to act on the surrounding mass of U-238". (My italics.) Wrong again.

The principal product of the breeding process, Bockris goes on, is plutonium; and he states correctly if eccentrically that "plutonium is like uranium-235 in that it can be induced, under bombardment, to undergo fission, and thus produce a large amount of energy per act." That is why plutonium is potentially a valuable energy source: see e.g. *The Use of Plutonium,* ATOM No. 282, April 1980, and *Fast Reactors,* ATOM No. 287, September 1980. But Bockris goes on in his treatment to assert that "breeder reactors produce plutonium as a waste product...." Skipping over the pages we read that if there were 1 000 reactors operating by the year 2000 these would produce 230 000 kg of plutonium a year, and 700 000 kg a year worldwide (which leads one to ask where the balance of the 700 000 kg would be being produced – presumably, outside the US), and that if there were by then seven billion people in the world and all but 700 kg of the plutonium were recycled "the amount of plutonium per person would be 100 micrograms, stored somewhere". Answers to the "problem" of storage of this massive 100 micrograms per person "all . . . involve transportation over long distances and the dangers of accidental spillage and hijacking." Under the next sub-heading in this chapter, **Hijacking,** we read that "it is easy to make an atomic bomb . . .". No, it isn't.

J. Daglish

Dr Walter Marshall to succeed Sir John Hill as Chairman of UKAEA

Dr Walter Marshall, CBE, FRS, has accepted the Secretary of State for Energy's invitation to succeed Sir John Hill as Chairman of the UKAEA for five years from 22 February 1981, the Department of Energy announced on 23 October. Sir John is to continue as part-time chairman of both British Nuclear Fuels Ltd and The Radiochemical Centre Ltd.

Dr Marshall, who is 48, married and has two children, was born in Cardiff where he went to school. He took his B.Sc with First Class Honours in mathematical physics at Birmingham in 1952, and his Ph.D. in 1954. He joined the Atomic Energy Research Establishment at Harwell in that year and spent the two years 1957-59 at Berkeley and Harvard before returning to Harwell.

In 1960 he was appointed Head of Theoretical Physics Division at Harwell, and in 1964 he was made a member of the Research Group Management Board. In the same year he was awarded the Maxwell Medal for outstanding contributions to theoretical physics. In March 1966 Dr Marshall was appointed Deputy Director of Harwell with special responsibility for reviewing and reformulating the establishment's future programme. In February 1967 he received the additional appointment of Deputy Director of the Research Group. He was appointed Director of Harwell on 1 April 1968, and Director of the Research Group (which included the Culham Laboratory as well as Harwell) on 1 April 1969. He was appointed a Member of the UKAEA in May 1972, and became Deputy Chairman in December 1975.

Dr Marshall and (right) Sir John Hill

From 1 July 1974 to 1 September 1977 Dr Marshall also served as the Department of Energy's Chief Scientist on a part-time basis.

Dr Marshall was elected Fellow of the Royal Society in 1971. He was awarded the CBE in 1975 and the 1975 Glazebrook Medal by the Institute of Physics for his successful direction of research and development work in the UKAEA.

Sir John Hill was born in 1921 at Chester. He was educated at Richmond (Surrey) County Grammar School, at King's College, London where he gained his B.Sc. and at St John's College, Cambridge, where he gained his Ph.D. After serving as a Flight Lieutenant in the Radar Branch of the RAF during the war he returned to Cambridge to do research at the Cavendish Laboratory. In 1948 he took an appointment as a lecturer at London University, a post he resigned in 1950 to join the Department of Atomic Energy at the Ministry of Supply. During his career in the UKAEA from 1955 to 1963 he has held the posts of Assistant and Deputy Director of Technical Policy, Industrial Group; Deputy Director, Technical Operations Branch, Industrial Group; Technical Director, Deputy Managing Director and Managing Director of the Production Group. He was appointed to the Board of the UKAEA as Member for Production in 1964.

Sir John succeeded Lord Penney as Chairman of the Authority in 1967, and in 1969 he was created Knight Bachelor. When British Nuclear Fuels Ltd was formed in 1971 Sir John was appointed Chairman and in 1975 he succeeded Sir Charles Cunningham as Chairman of The Radiochemical Centre. Sir John, who is married with two sons and a daughter, is a Freeman of the City of London.

The Secretary of State for Energy appoints the Chairman and Members of the UKAEA under the Atomic Energy Authority Acts of 1954 and 1959. □

Hunterston B inaugurated

The twin-reactor Hunterston B nuclear power station owned and operated by the South of Scotland Electricity Board was inaugurated formally on 25 September by Sir Monty Finniston, FRS, chairman of the Government Working Party on the Engineering Profession and a man who has had a long association with the nuclear industry.

Hunterston B and the Hinkley Point B station of the Central Electricity Generating Board are the first of the five Advanced Gas-cooled Reactor power stations built in Britain during the past decade come to come on line. A development of the design of these stations has been chosen as the basis for the Torness nuclear station now under construction on the Lothian coast near Edinburgh, and the CEGB's second station at Heysham, each of which will have an output of 1 200 megawatts electrical. Each of the reactors comprised in the Hunterston B station is restricted temporarily to an output of 550 MWe.

Mr Roy Berridge, chairman of the SSEB, acknowledged at the inauguration ceremony that the early AGR programme had suffered setbacks. The construction period for the first unit of the station had been eight and a half years, two years longer than the Board would now consider sensible for a non-prototype plant of its size and quality, but within the range of construction times for large contemporary pressurised water reactor units in the United States. All the new technical problems encountered in the building of the station which led to delay had been overcome successfully, and would not recur on future stations.

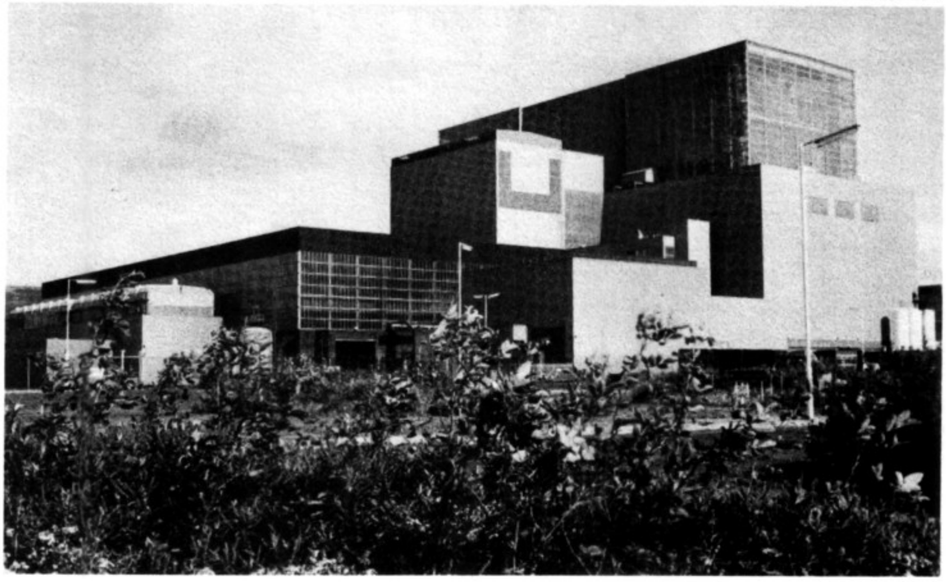
"As regards reliability, the load factor for the first unit (R3) has been rising steadily year by year. Last year it was 51 per cent, in the first part of this year it was 66 per cent and we are confident that it will go higher," said Mr Berridge. "It compares well with the early operation of most coal-fired plants and with contemporary American reactors.

"The second unit returned to service in February this year [after an outage beginning in October 1977] after the well-known seawater incident, and shows no sign of any ill-effects. Let me stress again that the seawater incident was in no way due to any weakness in the design of the plant, neither is an outage of that duration unique to nuclear plant. A number of conventional turbine generators have been out of service for similar periods throughout the world."

Mr Berridge noted that the reactors at Hunterston had been limited in output to an interim rating of 550 MWe because of uncertainty about the long term corrosion behaviour of one of the alloy steels used in the boilers. Long term tests were confirming its suitability, and the Board was stepping up the output progressively.

"The purpose of the station of course is to produce low cost electricity, and it is certainly doing that," he said. "The total generation cost of this station now (including the capital charges, fuel and operating costs and with provision for decommissioning at the end of life and for glassification of the radioactive waste) is less than the generation cost of our large coal-fired station at Longannet which was built earlier when price levels for labour and materials were lower. The gap between them will widen as Hunterston B becomes fully mature and as fuel prices rise, because the cost of generation at coal-fired stations is much more sensitive to fuel price increases. Hunterston B, like other nuclear stations, will help us fight inflationary pressures on tariffs. All in all, Hunterston B is a real success story, especially when one realises the enormous scale and complexity of the plant and its prototype nature. Buying and operating power stations is not like buying the current model of a motorcar or aeroplane off the shelf. Each one is a major engineering project."

Based on their experience with Hunterston B, the SSEB was proceeding with full confidence to build a "Hunterston B Mark II" at Torness, he said. Construction was already under way and was going well. "Because of inflation the plant will cost a lot more than Hunterston B did – but then so does everything including other types of power stations and other fuels. The really important point about Torness is that its *total* cost of generation will be so much lower than the *fuel* cost alone of the plant that would otherwise have



to run that it pays us and our consumers handsomely to build it just as soon as possible. Indeed, there is no other step we could take with such a powerful stabilising effect on the cost of electricity in the medium-term future. And we can only do this because we have made a good job of Hunterston B."

Imperatives

Sir Monty Finniston urged in his address that the supply of electricity had become a "must" of modern society. The consequence of not having electrical power – evidenced in an unintended blackout in the United States – "is not just an abnormal increase in the population nine months later but a limitation in the economy which cannot be met by other options, since there are none," he said. "It has been said that we live in an era in which the two great determinants of any economy will be information and energy, but whereas information is infinite and unbounded, energy sources as we use them today are wasting assets, the demand for which may be infinite but is bounded."

In the future as it should have been in the past one could not ignore any resource which supplied energy. "When one looks at the developed world today and even the developing world, one sees examples of esoteric measures now being actively explored to provide such energy – wind and wave, fusion, solar energy in its many forms from the intermediate growth of crops for burning to direct generation or even transmission from satellite stations. There are proponents and opponents for each of these. I am unashamedly a pro-nuclear advocate, but this does not make me an anti-fossil fuel lobbyist. To neglect the provision of energy through nuclear fission would be unrealistic and difficult to justify. Where the balance should rest is a matter for continuing calculation and policy determination (not political in the social sense) always bearing in mind that the decisions on balance, if they have to be translated into reality, require some long time, of the order of a decade, between conception and realisation."

The Hunterston peninsula, just south of Largs in Ayrshire, is the site of both the Hunterston B and the older and smaller A station, which is equipped with Magnox reactors. The A station, opened in 1964, has a life-time load factor of 82 per cent, which the SSEB claim as the best operating record in the world for any nuclear power station.

Hunterston A and B together provide 1 200 permanent highly and semi-skilled jobs, and produced jointly about 4 670 million units of electricity in the year ended 31 March 1980. A further 1 410 million units were generated at the Chapelcross and Dounreay nuclear stations of British Nuclear Fuels Ltd and the UKAEA, bringing the total contribution from nuclear sources to electricity generation in Scotland in that year to 21 per cent.

Hunterston B cost £143 million to build (excluding the initial fuel charge) against an estimated cost of £97 million when construction began in 1968. About £30 million of the £46 million overrun was attributable to inflation, and only £16 million related to 'prototype' problems. The seawater incident which put R4 out of commission for more than two years gave rise to a bill of £15 million for essential repairs; there was an additional cost of £42 million in providing electricity from non-nuclear generating sources as a result of the lost output from this reactor – a figure which the SSEB says "itself is a clear indication of the lower cost of nuclear generation." □

IAEA DIRECTOR GENERAL:

"Paradox and confusion"

Dr Sigvard Eklund, Director General of the IAEA, spelled out the paradox of hostility to nuclear energy in the face of world energy supply difficulties, and the present confusion in the nuclear industry, when he addressed delegates to the Agency's General Conference in Vienna in late September.

"In many countries we seem to be in the midst of a re-assessment of the fundamental values which have provided a basis of the industrial society for more than a century," he said. "These values assumed that through exploring the secrets of nature it would be possible to tame and use the natural resources, and thereby eliminate the drudgery of manual or repetitive work and raise standards of living everywhere: in short to make material progress possible on a large scale.

"For their own reasons the advocates of these ideas have come to regard nuclear energy as the archetypical example of high technology, which in their belief is not required as they seem to be content with their present condition. They seem quite oblivious to the lot of the vast majority of mankind—some two to three thousand million people—who can barely afford the necessities of life, let alone a reasonable standard of living.

"We thus face the paradox of hostility to nuclear energy at a time when the present industrial pattern is consuming oil so quickly that the world runs the risk of exhausting its reserves within a few decades, and when the rising price of oil is causing grave imbalances in world economy."

The recent World Energy Conference had cast some light on this confused situation, he said. There had been overwhelming agreement on the need to use nuclear energy so as to diminish the consumption of oil; there had been discussions on the need for nuclear power in the developing countries, whose energy problems were one of the main themes of the conference, there had been stern reminders of the environmental and even global consequences of burning large quantities of fossil fuel; there had even been a sense of urgency as expressed by one participant in the words "we have energy, what we lack is time"—referring to the transition between fossil and nuclear fuels.

"Until there is a resurgence of demand for new nuclear electric capacity, the fundamental question remains: how and how long can the nuclear industry hibernate or even survive without new orders? Not only is the nuclear industry itself affected, there are also signs that there may be an ominous decline in the professional manpower, even in universities, needed to service it."

Dr Eklund noted that the size of the standard unit still presented an obstacle to the introduction of nuclear power in developing countries. Estimates showed that no more than ten of the developing countries of Asia, Africa and Latin America would be operating nuclear plants by the year 1990 and that—at most—about 20 would be operating nuclear plants by the year 2000.

The world was entering a new decade, and the harsh realities of the energy supply crisis were beginning to have an impact in public consciousness. The public had perhaps been lulled into a false sense of security when oil was cheap and plentiful and when solar energy and other alternative sources of energy seemed to offer "quick and easy" solutions. Now, in many countries, there was a growing momentum toward energy conservation, and perhaps the beginning of a realisation that each form of energy production had its advantages and drawbacks—and that all of them would be needed.

Safety and Safeguards

Dr Eklund drew attention to the "extraordinarily good" safety record of the nuclear industry. It was astonishing that the media did not pick up this fact: the absence of a single radiation induced fatality in nearly 2 000 reactor-years of operating experience at 235 commercial nuclear power plants, he said; it was doubtful whether there were many other industries, and certainly there was no other energy industry, that could claim a comparable record. Nevertheless, the nuclear industry had lost no time in putting into practice the lessons of the incident at Three Mile Island. The Agency was putting even greater emphasis on operational safety and on improved training programmes which recognised the importance of the human factor.

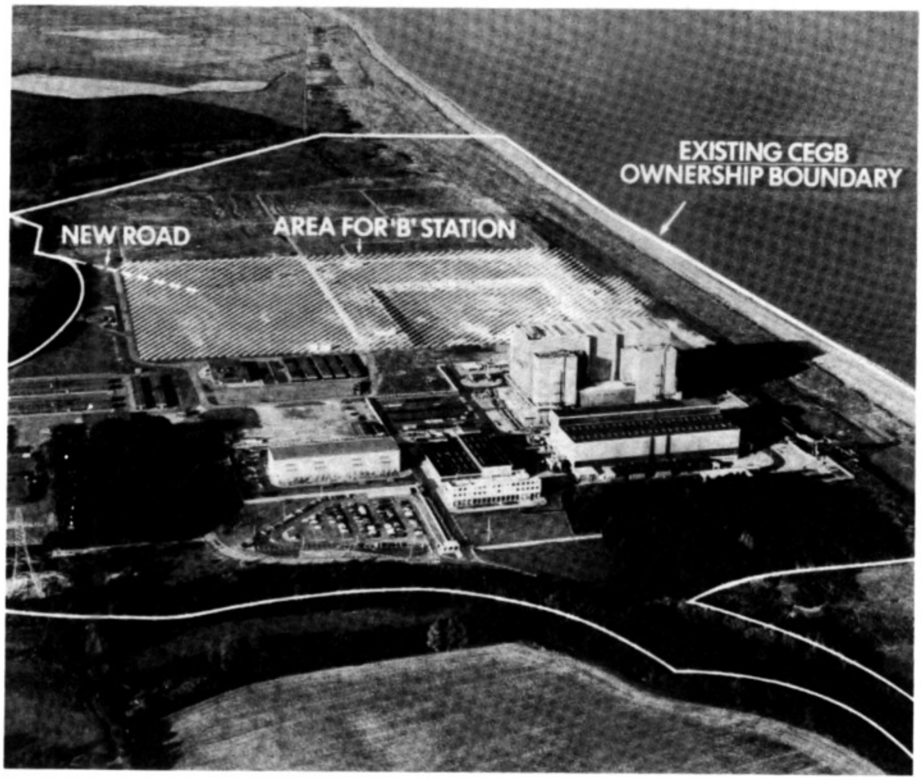
The second review conference on the Non-Proliferation Treaty had underlined that although 113 countries were parties to the Treaty there was no room for complacency. There were states—apart from the nuclear weapon states—that were operating or constructing unsafeguarded facilities. However "respectable" the intentions of the states concerned might be, one could not escape the political fact that the operation of unsafeguarded reprocessing or re-enrichment plants automatically engendered fears of plans to acquire nuclear explosives. The destabilising effects of such fears in the regions concerned were abundantly clear.

It would perhaps be naïve to expect in these cases that the nuclear problems could be resolved in isolation from the broader political problems involved, Dr Eklund acknowledged. However, adding a nuclear dimension to these political problems—far from increasing national security—was likely in the long run to present it with the gravest possible threat, and could lead to the unravelling of the whole fabric of non-proliferation. On the other hand, the acceptance of full-scope safeguards by these countries would make a major contribution to the security of the regions to which they belonged, and to the establishment of additional nuclear-weapons-free zones. More specifically, the early conclusion of a comprehensive Test-Ban Treaty would be a major step to help make the NPT regime universally acceptable. Unlike the NPT, a comprehensive Test-Ban Treaty would apply equally to nuclear and non-nuclear-weapon states and would thus be secure against charges of discrimination.

"After the establishment of an IAEA safeguards system, and the Tlatelolco and Non-Proliferation Treaties, it is deeply regrettable that the confidence which so much fostered the nuclear trade in the 60s and early 70s has been eroded," said Dr Eklund. "Concepts like prior consent and good non-proliferation credentials can also be a cause for uneasiness as, carried to logical conclusions, these could lead to situations where customers and consumers might feel the necessity of shaking off dependence on outside enrichment and reprocessing services by establishing their own facilities for such purposes.

"Discussions at the NPT Review Conference showed how important it is to work towards greater security in the supply of nuclear materials, plant and technology, and at the same time strengthen assurances against proliferation." □

CEGB designate Sizewell for first PWR



The Central Electricity Generating Board announced on 1 October that it had selected its site at Sizewell, near Leiston on the Suffolk coast, as the proposed location for Britain's first nuclear power station based on the Pressurised Water Reactor (PWR). The development cannot take place unless the necessary consents and safety clearances are obtained.

The Board said preliminary information on the Board's proposals was being made available at this stage so that discussion could begin immediately. The next formal step is likely to be in early 1981, when the Board said it expected to apply for statutory consent, a nuclear site licence and other necessary permissions for the station—a complex of about 1 200 megawatts electrical capacity to be known as Sizewell B. It expected that a wide-ranging public inquiry into the proposals would take place in 1982; for this purpose, detailed information on the proposals, including safety documentation, would be made available to the public when the design of the station was sufficiently developed. The Board also announced that in time it was likely to seek the further development of the site, to add another 1 200 MW of capacity.

The announcement that Sizewell had been chosen followed the statement by the Secretary of State for Energy, Mr David Howell, in December 1979 [ATOM No. 280, February 1980, p. 34] on the future British nuclear programme. Mr Howell told the Commons that it was the Government's wish that, subject to the necessary consents and safety clearances, the PWR should be the next nuclear power station order after the two AGR stations authorised earlier. The CEGB has since authorised the National Nuclear Corporation to prepare design proposals for the new Sizewell PWR station, basing the nuclear steam supply system on technology developed by the US Westinghouse Electric Corporation.

"Foolish" to reject nuclear option—Hildrew

In the context of the capital resources of energy available to man it would be "foolish" to reject uranium fission, Mr Bryan Hildrew, President of the Institution of Mechanical Engineers and managing director of Lloyds Register of Shipping, said on 22 October.

"It is the only energy source for which we have no other use and its utilisation to date has established a technological competence within this country [the UK] which is second to none," Mr Hildrew said in his Presidential address to the Institution. "Not to take advantage of our expertise is to destroy it and ultimately to face the reality of purchasing the technology from far-sighted nations."

Mr Hildrew steered clear of the debate over reactor choice, but said that if the decision to build pressurised water reactor power plant in the UK depended upon the integrity of the primary circuit "it must be stated categorically that the reactor vessel and its associated pipework can be designed to meet the most critical independent technical assessment, that the materials of manufacture can be seen to be manufactured to the stipulated high standards and that the workmanship can be subjected to the independent assessment of engineers with long and in-depth experience in the construction of such plant. In addition, the technology exists to ensure that periodic inspection can identify any deterioration in the integrity of the pressure parts. Theoretical judgments lacking the knowledge and the reality of proven quality manufacturing procedures should not be assumed or tolerated as equal to or better than the operational success of pressure plant in modern high technology processes."

Mr Hildrew said the proper management of the UK's nuclear resources required that we also maintain a competence in fast reactor engineering. "Here again an investment in our long term future energy requirements is called for," he said. "The utilisation of the plutonium fuel created in our thermal reactor programme will enable a balanced nuclear fuel economy to be developed which will ensure that at least a minor portion of our energy load is assured for many decades to come."

Mr Hildrew stated the truism that civilisation as we know it depends utterly on a plentiful supply of energy. "Its further progress and continued extension to the under-developed nations will result in an ever-increasing demand in the world energy supply," he said. "For example, the current annual growth rate has been estimated at some 4-5 per cent, i.e. a doubling in demand approximately every 20 years. Yet only in very recent years has industrialised society become fully conscious of the relatively limited natural reserves of the world's traditional energy resources—fossil fuels and more recently nuclear fuels. Estimates of the remaining resources vary widely but there is little doubt that at current growth rates demand will outstrip supply capacity within the next century and, in the case of oil, within a very few decades. To aggravate the situation, progress in the petro-chemical industry has now resulted in a dependence on a wide range of vital by-products affecting almost every aspect of modern life. Such examples as medicine, agricultural fertilisers and disease controls, plastics and synthetic fibres may logically be regarded as having an equal if not higher claim on the remaining reserves of fossil fuels than that of energy production.

Response to challenges

"However, the history of man's technological progress has always been characterised by his ability to respond to a technical challenge and develop alternative or modified technology to meet changing circumstances," Mr Hildrew continued. "It is necessary that governments and industry take a responsible attitude to the financing of the necessary research and development activities.

"In this respect, economics is proving to be the most powerful factor motivating progress, and, assuming its continued influence, one can make a reasonable prediction of the various stages of progress towards the ultimate solution to the energy problem:

- Continued expansion of the search for new reserves of fossil and nuclear fuels;
- increasing emphasis on energy conservation programmes;
- a redistribution in the balance of demand for oil, coal and nuclear energy more consistent with the availability of reserves;
- an intensification of existing development programmes related to the harnessing of renewable energy sources such as solar power, wave, wind, tidal and geothermal energies;
- and the expansion of research effort into entirely new energy source concepts."

Mr Hildrew stressed that there was a pressing need to convert energy demands to alternative fuels wherever possible. Continuing increases in the oil price and the comparative rates of development in combustion and fuel handling technology made it inevitable that the wide use of coal as an energy source would be re-established ultimately. Although potentially capable of making a contribution to energy requirements the "renewables" could not in his view be considered to represent a principal energy source: they were, however, the only sources of continuously available energy since, by definition, all other sources were exhaustible.

"The UK has an excellent position to benefit from wave power, it being estimated that some 15 per cent of our current requirements could be supplied from our coastal waters," he said. "Consequently, while by no means ignoring the potential of other renewable sources, we have tended to put most effort into the development of wave energy converters. The emphasis in other geographical locations is largely determined by their geological and climatic conditions.

"There is also the possibility of utilising tidal power where the geographical configuration lends itself to such development. Again the UK does have one or two places where tidal barriers would make significant long-term contributions to our energy supply. Unfortunately, such developments require very large capital investment and take many decades to bring to fruition. A country needs to invest in more than its immediate future and to have a wider vision than its immediate advantage. Thus the exploitation of this particular source of long-term energy should be given a much higher priority in this country's energy programme."

Long-term projects such as he had been discussing required identification, agreement and a united commitment by the engineering profession to ensure their safe and proper development, said Mr Hildrew. The engineer of today and tomorrow must be educated and trained to meet the challenges, and must always be prepared to change and adapt to developing technologies. □

JET buildings inaugurated

Two buildings for use by the JET Joint Undertaking—a main office and laboratory complex, and a laboratory and workshop building—were inaugurated officially at a short ceremony at Culham on 16 October.

The buildings have been provided by the UK as host nation as part of its contribution to the JET project. The project was described in the November issue of ATOM.

Sir John Hill, Chairman of the UKAEA, said at the inauguration ceremony that the decision by the Council of the European Communities to construct a large facility of the tokamak type as a major part of the Euratom programme was one which all hoped would keep Europe among the leaders in fusion research. Now that the first two buildings were complete and there were rising beyond them the main experimental hall, power supplies and support buildings which were being constructed by the JET Joint Undertaking it was easier to appreciate the scale of the project.

The first part of the ceremony was conducted in a lecture theatre and conference chamber which forms part of the main office complex; the JET Council was to meet in its own chamber for the first time later in the day. Sir John said the authority as the British member of the JET Joint Undertaking had been privileged to join in and witness substantial and speedy progress during the 18 months which had elapsed since site excavation first began, and he paid a warm tribute to the chairman of the JET Council, M. Jean Teillac, for the way in which he and his Council had conducted the affairs of the Joint Undertaking. "I will not dwell on the ease or difficulty with which consensus is reached in international meetings—the problems are well known," said Sir John. "I would however like to take this opportunity to acknowledge that your wise leadership has enabled the imaginative plan of the design team to move quickly towards a material reality. We are glad to have had a part in this progress."

Sir John said the war in the Middle East was a sharp reminder that the background against which it had been decided to build JET had not changed. "Oil resources of the world are limited and alternative energy sources must be found," he said. "Nuclear fusion as a commercial reality is a long-term aim, but it requires an investment now, beyond that which any one European nation can afford, in order to realise the hope that fusion power will significantly reduce the dependence of Europe on external energy sources."

M. Teillac congratulated the UKAEA on the "excellence" of the buildings. "As Sir John said, 18 months ago this site was farmland," he said. "It is a tribute to his organisation, the Authority, to British building contractors, and the work force and perhaps even the British weather that we are able to hold a meeting of the JET Council today for the first time in our own conference chamber. It is an achievement of which we are all truly proud."

The handing over of the building represented much more than just the fulfilling of certain conditions of the support agreement between the UKAEA and the JET Joint Undertaking. It was a clear case of commitment and cooperation aimed at the achievement of the project.

M. Teillac said he expected that the JET device might be able to start operation by the latter half of 1982. "JET should answer the question whether controlled fusion is scientifically feasible," he said. "Thus, it will be a major step toward fusion as an energy supplier. Other steps will be as necessary and important and also, to say the least, as difficult. I am sure Europe will participate in this scientific and technological venture, for this is the main area in energy research where cooperation and coordination exist at a European level." □

Sir Francis Tombs

By agreement with the Secretary of State for Energy, Mr David Howell, Sir Francis Tombs, chairman of the Electricity Council, is to relinquish his appointment on 31 December this year instead of completing his term of appointment, which would have extended to 31 March 1982.

Sir Francis' request to be allowed to leave early followed the Government's decision, announced by the Secretary of State for Energy to the House of Commons on 14 July, that legislation would not be introduced to change the organisation of the electricity supply industry in England and Wales.

A statement from the Electricity Council issued on 7 October said Sir Francis was invited to become chairman of the Electricity Council from 1 April 1977 on the understanding that the organisational framework of the industry would be changed by legislation following the report of the Plowden Committee of Inquiry in January 1976. He made it clear at the time that he accepted the appointment on that basis, and had no wish to become chairman of the Electricity Council under the 1957 Act which, he agreed with the Plowden Committee, was unsatisfactory.

The statement recalled that the previous Administration had announced its intention to legislate for a changed organisation of the electricity supply industry in England and Wales and had published a draft Bill in April 1978, but had not proceeded with it. "The present Government examined the problem during its first year in office and concluded that legislative change was unnecessary and that more co-operative working under the 1957 Act, with a more positive role being taken by the Electricity Council, offered a more satisfactory solution to the problems identified by Plowden and others," said the statement. "Sir Francis had advised the Secretary of State against this course, and feels strongly that the essential structural problems of organisation will remain. As a result he asked to be allowed to leave early." □

AEA REPORTS

The titles below are a selection of reports published recently and available through HMSO.

AEEW-R 986 *Analysis of the SEFOR 1 and 2 Doppler experiments and their use in assessing the accuracy of calculated fast reactor Doppler effects.* By A.T.D. Butland. July, 1975. 98pp. HMSO £4·00. ISBN 0 85182 041 7

AERE-PR/EMS 7 *Environmental and Medical Sciences Division progress report January-December 1979.* Compiled by W.M. Hainge. June, 1980. 161pp. HMSO £7·00. ISBN 0 70 580732 0

AERE-R 9582 *The quality control of Iodine-123 produced on the Harwell variable energy cyclotron.* By J.A. Winter. July, 1980. 15pp. HMSO £2·00. ISBN 0 70 580822 X

AERE-R 9586 *Computation of ion implantation uniformity.* By W. Temple, D.G. Beanland and A.N. Bridgwater. February, 1980. 50pp. HMSO £3·00. ISBN 0 70 580542 5

AERE-R 9770 *The physical basis of remote sensing measurements at sea.* By M.H.B. Thomas. April, 1980. 49pp. HMSO £1·50. ISBN 0 70 580702 9

AERE-R 9878 *Practical guide to the Pluto small angle scattering spectrometer.* By D.I. Page. August, 1980. 57pp. HMSO £3·00. ISBN 0 70 580842 4

ND-R 451 (S) *Nuclear applications of modern analytical techniques. UKAEA diffraction analysis conference, 27th meeting, Fast Reactor Training Centre, Dounreay, October 9-11, 1979.* Edited by I.F. Ferguson. August, 1980. 76pp. HMSO £4·00. ISBN 0 85 356130 3

AERE-R 9910 *Correlation factors for diffusion in dilute interstitial solid solutions.* By A.D. Le Claire. August, 1980. 15pp. HMSO £2·00. ISBN 0 70 580942 0

AERE-R 9938 *A concise guide to PL/1.* By P.A. Shovlar. September, 1980. 51pp. HMSO £3·00. ISBN 0 70 580992 7

AERE-R 9807 *Studies of environmental radioactivity in Cumbria. Part 1. Concentrations of plutonium and caesium-137 in environmental samples from west Cumbria and a possible maritime effect.* By R.S. Cambray and J.D. Eakins. July, 1980. 20pp. HMSO £2·00. ISBN 0 70 580792 4

The following reports are available from Editorial Section, Safety and Reliability Directorate, UKAEA, Wigshaw Lane, Culcheth, Warrington.

SRD R171 *A Guide To The Use Of Floors – A Computer Program For The Calculation Of The Dynamic Nodal Responses Of Damped Lumped-Parameter Systems.* D.W. Phillips. August, 1980. £3·00

SRD R182 *The Direct Calculation Of Floor Response Spectra.* D.W. Phillips. September, 1980. £2·00

SRD R184 *Sensitivity of Fission Gas Release From Fuel To Gas Bubble Mobility.* I.R. Brearley, D.A. MacInnes. August, 1980. £2·00

HSE publish 2nd Quarterly Statement

The second quarterly statement of incidents at nuclear installations in Britain in 1980 reported to the Secretaries of State for Energy and for Scotland was published on 2 October by the Health and Safety Executive.

The incidents reported occurred in the period 1 April to 30 June; the statement contains as well summaries of investigations into incidents reported previously which were completed during the quarter. The installations mentioned in the statement are Hunterston nuclear power station, the Windscale works of British Nuclear Fuels Ltd, the Wylfa nuclear power station, the Berkeley Nuclear Laboratories of the CEGB and the Trawsfynydd nuclear power station.

Copies of the statement are available from the Enquiry Point, Health and Safety Executive, Baynards House, 1 Chepstow Place, London W2 4TF. Tel. 01-229 3456, ext. 6754. □

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