PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

Energy for 1000 Years: Introduction to Discussion [and Discussion]

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Energy for 1000 years: introduction to discussion

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To conclude the excellent and highly authoritative set of papers, the Organizers hope that this final discussion will be one of the most important parts of the meeting, one in which we would value particularly comments and impressions from some of you not involved so closely with the programme as are many of us.

Energy for 1000 years. How very appropriate it has been for the Royal Society to have organized this meeting. The motto chosen by our early Fellows for our Coat of Arms in 1663 was 'Nullius in Verba', which expressed their determination that all statements should be verified by an appeal to the facts. The statements we have heard on all aspects of the fast reactor system have been justified most comprehensively, starting from a sound understanding of the underlying science through development of the technology and engineering to demonstration by large-scale operational experience. Here I think we should pay tribute to the work of outstanding scientists in many countries whose pioneering work laid such firm foundations for the later technical developments – work not just in the physics of the breeding process but including the complex interplay of many specialities – solid state phenomena, radiation and separation chemistry, thermodynamics and metallurgy among others. This scientific base has stood us in good stead in the face of changing requirements from licensing authorities and the general public for ever greater assurance on safety and environmental issues and from industry for assurance on performance and economics before embarking on anything new.

We have heard of impressive progress towards commercial power producing and fuel process plants. The fact that problems arose in the prototypes and have been overcome adds to my confidence in these future plants. I do believe that what has been achieved has been truly miraculous, and that is not too strong a word. Turning an otherwise nearly useless material – ^{238}U, previously suitable only for glazing pottery and more recently for the keels of high-performance yachts – into potentially the world's most abundant low-cost fuel for electricity production – at least 10 times our fossil fuel reserves – is surely miraculous. Almost as miraculous has been the size and consistency of the support of this technology by several governments as a far-sighted piece of energy policy for 30 years which has brought this about. For those of us in Europe another near miracle has been the recent completion of the slow but finally sure process to complete cooperation in research, design, construction and, most important, of the customer utilities. That we now do have the potential for an attractive, economic source of energy for 1000 years has I believe, been verified by as complete and convincing appeal to the facts as our early Fellows could have wished.

So now we have a technology already more soundly based than was the case for any other power system before its large-scale use. One with many benign features, due in certain respects

† Died 12 October 1989.

to operation of the laws of nature, not just the skills of engineers. These are aspects in which competing nuclear and indeed fossil-fuelled plants are now being examined for improvements. These will no doubt be obtained, but I suspect at costs to the advantage of fast reactors.

With this background our purpose now is to consider what should come next in this research and its utilization; the latter aspect was to me the least convincing part of the presentations so far. But now is the opportunity for the protagonists of their present strategies to convince us of their correctness. Certainly I find it hard to quarrel in general with the move towards less government funding in several countries as they have been very fair in contributing to the stage at which well-founded decisions can be made by the industries involved. However, in the case of this country it seems to me unfortunate and unwise for major cuts to have been imposed immediately before setting up an entirely new structure for the electricity supply industry.

Future trends in research are perhaps the simplest matters for our consideration. It will be interesting to hear from people not directly involved as to whether they feel key basic and economic parameters are now sufficiently well established. I believe them to be, leaving us primarily with development, and I found the various programmes described very impressive. I, personally, was not persuaded of the view that further research on new concepts or revisiting old ones such as small reactors and metal fuel is necessary or likely to be rewarding. As we have heard there is important work in hand to bring out the best in present concepts which must be completed, particularly such things as establishing the optimum performance of the fuel and ensuring the most effective application of the physics of inherent safety. I hope that sufficient attention is being given to process plants including simplifying their instrumentation for example and, most important, in seeking to ensure that the permanent parts of both reactors and reprocessing plants have lives of say 50 rather than 30 years. But these are relatively minor points. Overall I think continuing preoccupation with research will be increasingly wasteful.

The real issue for discussion seems to me to be whether or not anything more should be done about utilization. In this country, and perhaps in others, there seems real danger that decisions and programmes are being distorted by the politics of very-short-term issues, not primarily by serious study of the very comprehensive data available. I feel either we should be more energetic in seizing the opportunities now open or alternatively consider more rewarding use of the skilled resources deployed if that is really what emerges. In such consideration I suggest greater regard needs to be taken of two things. The likely impact of the needs of developing countries for energy over the next few decades. It surely cannot be right to assume continuation of the present situation in which 25 % of the world's population use 90 % of its fuel, and these countries could not themselves benefit directly from fast reactors. Also there could be advantages from more diversity in our own electricity supply systems.

The lesson that stands out in the energy scene is that we should have as much diversity as we can afford to cover the very long timescales involved in system planning. There is a strong likelihood of an increasing nuclear component in total electricity supply and I suggest there should, if possible, be diversity in that as well as in the system as a whole. For the United Kingdom some estimates suggest we might require replacement and new generating capacity of some 50000 MW or even up to 80000 MW in the next 30 or so years and that half of that might be nuclear. I doubt if it is wise to plan on all this being of one type with one set of safety and logistic characteristics when, by taking more resolute action to establish an industrial base to supply fast reactors and reprocess their fuel, we can have diversity well within this period. Fast reactors, as always intended, are the perfect complement to present thermal reactors. As

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we have just heard, they have very similar and probably lower generating costs when properly established, alternative inherent attractive safety features and no problems of fuel supply. Unlike other candidates for diversity they actually improve, not detract from the economics of existing plants, increasing the value of both the nuclear fuel discharged from them and of their existing reprocessing plants. A true complement not a competitor.

Even ignoring increasing problems of the approaching need to replace expensive research and test facilities in which to continue development work with an ever deteriorating benefit to cost ratio and the practicality of replacing existing skilled research and experienced engineering and design teams at a time when due to population trends competition for technical staff will be increasing with supply diminishing I did not find the justification for delay convincing. It is surely imprudent to assume one can see 30 years ahead very clearly and this is the minimum time before any new system can really make its presence felt. Such long-term forecasting is required to justify delay, let alone cancellation. My reading of the position is that on diversity arguments the position of minimum regret and probably greatest benefit would be to provide part of our nuclear component from fast reactors as soon as practicable. Delay will be very likely to increase costs and reduce benefits.

Of course some of the essential preliminaries for this are in progress around the world. The European programme represents major advances through the pooling of resources and efforts to establish an adequate market through common European specifications and safety standards. What seems to be missing at present is a definite scheme to establish the ordering pattern and industrial base necessary for the system to be saleable in the present economic climate. In some respects the position seems to have worsened from the earlier European concept of having three early stations in three countries. One consequence of this, for example, was that reprocessing fuel from all these in one plant, rather than separately, would have produced the same reduction in generating costs as development and design improvements reducing the capital costs of the nuclear island by 20 %. Not too easy to achieve. A strategy of 'just in time' may be correct for car assembly plants. What I do not see succeeding is a strategy of 'one at a time' for future fast reactors. This is particularly true now when I see no willingness by governments to pay further first-off or once-off costs. Nor of industry to set up specialist teams and facilities for a once-off plant except at very high premium costs. Nor is there likely to be much willingness for electrical utilities to pay high first costs which are likely to benefit their competitors either by indirect effects on fuel supply or directly making subsequent plants cheaper. While I agree with the priority being given to designing a first plant in the EFR programme, its role in the process of commercialization is the next most difficult question waiting to be solved. Looking at the EFR design programme I see that design and development work planned for the next 4–5 years is expected to reduce capital costs from the present Superphénix 2 design by 7 %. But moving from the first EFR to multiple ordering will save five times as much, 35 %. Making that last step is the most crucial. It is only belief that this will be achieved that really justifies present activities, but more than this hope will be required to produce an economic system and make the first EFR project likely to be ordered. I hope the discussion will bring out views on what is in mind to achieve that. For example would an even wider collaboration among utilities be manageable and helpful? A way through must be found to early industrial-scale ordering – we must not fall at this final hurdle – and we shall soon need a clearer idea as to how this will be achieved.

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Discussion

B. Saitcevsky (*Unipede, France*). In thinking about the future we must not neglect the present. We now have several fast reactor plants working and their operation is a very important base for the future, especially for fuel irradiation. Dr Marsham suggested that plant lifetimes might be extended from 30 to 50 years. Such aspects can be checked using our current plants. In this respect it is disappointing that the British government proposes to shut PFR down in 1994. We should be aiming to take full advantage of what exists now.

D. A. Davis (*CEGB, London, U.K.*). Yes, but how do we establish a market to achieve series ordering?

B. L. Eyre (*UKAEA, London, U.K.*). I would like to state where I and my colleagues in the U.K. see our position. The only way forward for the U.K. is within the European collaboration, which we must also couple with wider international links so that we learn the lessons from the work being done throughout the world. We believe that the government's cuts in the British fast reactor programme funding were a major misjudgement. In particular, the timing was wrong at a period when fundamental changes were being made in organization of the electricity supply industry, meaning that there was little chance of the utilities making up the shortfall.

Dr Marsham said that more research is not needed. We agree, because the design of EFR is basically well founded and because we need to focus on demonstration projects. However, we do also need to underpin specific points of the design and should not repeat earlier mistakes of cutting back research too quickly. Funding cuts may mean we cannot validate EFR properly. One further question is should we keep all our prototype reactors in operation? It will be important to balance the costs and benefits of so doing against the costs of R&D for EFR. PFR was only designed for a 20–25-year life and extending this to 30 years may be the best we can achieve.

J. M. Cassels, F.R.S. (*Norwich, U.K.*). Not being a nuclear power specialist, I had no idea how high the load factors of fast reactors were, in particular the 70% load factor quoted by the U.S.S.R. There is thus no excuse for the popular view that fast reactors are unreliable. Again, I would have thought the use of liquid sodium as a coolant was a major safety problem, but long experience has shown this is not so. Hence we primarily have a communication problem and should be aiming to spread positive news in a simple enough form. Of course, it should also be recognized that the fast reactor is only one possible solution to future energy needs and MHD, fusion and CHP all may have their place.

R. Lallement (*CEA, France*). I would like to answer some of Dr Eyre's points. Yes, we are concerned about funding but we also see a need to keep a maximum of three fast reactors operating in Europe to demonstrate: high burn-up fuel, axially heterogeneous cores and major components and systems. We are not sure whether Superphénix will be available for such development work. Even though PFR was not designed for a life greater than 25 years, it must have an important future development role. As yet we have not completed the process of harmonizing R&D within Europe and have further savings to make.

F. D. Moles (*University of Surrey, U.K.*). The fast reactor can be considered as insurance for all our futures, though it may conceivably have a place in incinerating actinides, to reduce the long-term nuclear waste disposal problem. At this stage R&D is less important than the business of selling the fast reactor as an energy insurance policy. To summarize, I came here as a doubter, I am leaving as a supporter.

C. V. Gregory (*UKAEA, Dounreay, U.K.*). As one responsible for operation of PFR, I would like to endorse the points made by Dr Marsham and Dr Eyre about the timing of the British government's cuts. PFR (and Phénix) are now reaching the stage in their operating lives when they will yield the most important results relative to endurance of components and materials.

F. J. Barclay (*Energy Consultant, London, U.K.*). Perhaps it is appropriate to make remarks about the load régime set by the industry. If new base load generation is introduced the old plant is pushed into load following, which is very hard on nuclear plant. If load management policies were improved then operating régimes could be made more endurable and introduction of fast reactors would be eased.

D. A. Davis. I wish we were only worried about fast reactor load following. However, one point we have not addressed is the way that the industry proponents of the fast reactor can influence the decision makers. We need to emphasize the good points: diversity, economics, safety and conservation of resources.

L. E. J. Roberts, F.R.S. (*University of East Anglia, U.K.*). I would like to make two points. First, I doubt whether politicians will see the fast reactor as separate from the nuclear programme and the former can probably only be sold when politicians become convinced of the vital importance of nuclear development. There are some good signs. Despite doubts on economics, the developing environmental debate promises well for nuclear power. Secondly, the problems of disposal of mining wastes drive us towards using less uranium and thus towards fast reactors. However, we need to overcome the widespread view that fast reactors are more dangerous than thermal reactors and to this end an easily understood demonstration of safety needs to be arranged. Proliferation is not a new problem but it must be shown that it can be overcome.

M. Y. H. Bangash (*Middlesex Polytechnic, U.K.*). I suggest that Professor Roberts look for partners in the developing world, where there is no surfeit of power and where he will get a good press.

J. Walker (*Birmingham, U.K.*). I think the most important aim should be to avoid another Chernobyl-type accident. I was thus interested in Dr Hennies's demonstration of how the void effect in sodium can be balanced by temperature-dependent effects. There is a case for making temperature coefficients so strong that such a reactor could not possibly fail. This safety feature is perhaps the most important point to get across to the public.

B. Saitcevsky. May I make a proposal on the strategic problem we face. In the past there were optimistic nuclear programmes based on over-ambitious forecasts of electricity demand. Now we find that the conventional and nuclear plant market is static and the market for fast reactors

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depends on replacements for current nuclear plants. Because these plants are having their lives extended from 25 to 40 years, the fast reactor market may only appear in 20–30 years time. We need to link the R&D programme and operation of our present reactors to this timescale, but we also need to convince decision makers to consider replacing conventional plant by nuclear to advance these dates.

D. A. Davis. Would Mr Saitcevsky agree that the time frame is such that we should not reduce funding of fast reactor development, providing we continue to get value for money?

B. Saitcevsky. In the 1970s EdF decided to increase its nuclear component of generation from 10 to 70%. This type of difficult strategic decision will need to be taken in various countries if we are to have a market for fast reactors in 2010–20. We must think of the decision makers and address such things as cost, reliability and ease of operation.

D. A. Davis. Can I add that at present the CEGB, like EdF, funds fast reactor development work. Privatization of the industry, because of the loss of the obligation to supply, means, though, that the successor companies take a different view and will not provide such support.

F. D. Moles. I would like to emphasize the importance of timing to technological developments. As an example, 20 years ago the U.K. tried without success to sell incinerator technology to other countries. Only now, when many of the British plants are shut down, are world sales picking up. The only realistic source of support during the lean times, I am sorry to say, is the Government.

D. A. Davis. Let me end this discussion on a high point. The technology of fast reactors exists and is good. It is up to us to sell it as an international cooperative venture.

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