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E(80) 60
27 June 1980

COPY NO. 55

CABINET

MINISTERIAL COMMITTEE ON ECONOMIC STRATEGY

FAST REACTOR POLICY

Note by the Secretary of State for Energy

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1 Now that our thermal reactor policy is settled, we need to develop our approach to the fast reactor.

PERSPECTIVE

2 The fast reactor is much the best understood of the new energy technologies, capable of making a major contribution to UK energy supplies in the first quarter of the next century. From 2000 onwards we shall be moving into a period when, depending on the rate at which world nuclear programmes build up, uranium supplies will begin to constrain thermal power station ordering. Indeed we cannot rule out interruptions in supplies earlier than forecast for political or other reasons or because of the world energy situation. The efficiency with which fast reactors use uranium could be a very important element in energy strategy. Our existing stocks of depleted uranium used in fast reactors could be an energy source comparable with our recoverable coal reserves.

3 We must therefore make sure that by the end of the century we have available to us a proven technology ready for commercial ordering when we need it. I believe that to do so we shall need to build and operate a full-scale fast reactor in this country before then, subject to safety clearances and the full public inquiry which has been promised. We must also ensure that we have access to the necessary fuel cycle technology.

4 The alternative of relying on other countries to develop the technology and let us have a licence when we need it, running down our own programme in the meantime, is much less attractive. It would ignore the long leadtimes involved in introducing a new technology. It would assume that other countries would be prepared to let us have a licence on acceptable terms, which we cannot be sure about. And it would make no use of the considerable expertise in this field which we have built up over the last 25 years. The best way of acquiring experience with a technology of this kind is to build it, not import it.

5 Final decisions about the construction of a full-scale fast reactor and its timing are some years away. The first priority is to strengthen our nuclear industry and make a successful start on the thermal reactor programme which we have already announced. But we need to begin to formulate our fast reactor strategy now, to provide a framework within which existing work can continue and to make the most of our bargaining position with other countries, which is now worse than it was in the mid-1970s and will continue to weaken.

THE NEED FOR COLLABORATION

6 I believe that international collaboration must be an essential ingredient of our future policy. An independent effort based on a Commercial Demonstration Fast Reactor (CDFR) and its fuel cycle built to our own design would be costly and risky. The UK Atomic Energy Authority (UKAEA) put the cost at £4 billion over 20 years, an average of £200 million a year. As with any new technology there would be a considerable risk of problems arising which we would have to solve on our own with consequent delays and escalating costs. And we could not be sure at the end of the day of having a design which could be repeated with confidence.

POSSIBLE PARTNERS

7 The main possibilities for collaboration lie either with the United States or with France and Germany who are already in partnership supported by Italy, Belgium and Holland.

8 Collaboration with the Americans would have considerable attraction if it could be achieved, but we cannot be sure that it is a real option. President Carter has taken a firm stand against the early commercialisation of fast reactors. Even if policies changed after the Presidential election and the Americans wanted to collaborate with us rather than proceed independently or link up with the French, we could end up as a minor and unequal partner in any determined United States effort.

9 I believe therefore that the best prospects for collaboration at present lie in Europe, where the French are already well ahead with the construction of a full-scale fast reactor, Super Phenix, and that we should open negotiations with France and Germany to see whether we can obtain a satisfactory deal.

10 It would however be wrong to write off the possibility of an American deal completely at this stage. Negotiations with the French and Germans are unlikely to be concluded before the Presidential election, and we should keep open our contacts with the Americans at least until then in case there are major developments in United States policy or our negotiations in Europe are unsuccessful.

AIM OF NEGOTIATIONS

11 In talking to the French and Germans we shall need to be very clear what we want to achieve and not settle for less. The nuclear industry have had exploratory discussions but the terms on offer are not satisfactory and must be improved.

12 Collaboration must be genuine. We should seek a close integration of programmes which would enable us to draw on the proven experience of our partners, aim for a joint commercial design of fast reactor and enable our fast reactor, when it is built, to be phased into a common European series in which each reactor represents a progressive improvement in design and reliability and a reduction in cost. An arrangement which simply continued our line of development and only absorbed French experience at the margin would be nearly as risky as an independent effort.

13 Collaboration must also be a means of cutting costs, not only through the evolution of an economic, commercial design but also by coordinating investment in fuel cycle facilities and by cutting out duplication in research and development and test equipment. This does not mean that our partners would contribute to the actual cost of construction of our fast reactor; but the aim should be a significant reduction in the overall costs of the programme and a greater confidence in cost estimates for the project.

14 Collaboration must also be fair. We have to accept that the French are in the lead on reactor development. But we still have a lot of valuable experience, particularly on the fuel cycle, which should be reflected in the terms we set. Our industrial interests must be safeguarded. If we have to make royalty or other payments we must get real value for money. And we must have a proper say in the licensing of technology to third countries.

15 Finally, collaboration must not pre-empt our decisions on the timing of construction of our fast reactor. It is essential that I can say to the French (and other potential partners) that we intend to build a fast reactor in this country at a time when it suits us, but we do not need to commit ourselves now to a specific date. The nuclear and electricity industries say that construction could not begin before 1985 and I believe the right date may well be later than that.

16 It is far from certain that we can obtain a deal on these lines. But the Germans are keen to reach an arrangement, and there are incentives to the French to do so too. They feel exposed in their present lead on fast reactors; they could benefit from our expertise in a number of areas; and they would not wish us to join up with the Americans.

PUBLIC PRESENTATION

17 The French will express doubts about the seriousness of our commitment. It would help to deal with these doubts if we had given a public indication of our fast reactor strategy. We will not be in a position to make a major policy statement until the prospects for collaboration are much firmer. But I propose before the Summer Recess to make it clear in Parliament that we believe that we must have access to fast reactor technology when we need it; that in order to do this we plan to build a fast reactor in this country in due course though construction is unlikely to begin before 1985; and that we are exploring actively the possibility of international collaboration. I will also stress that construction of a full-scale fast reactor will be subject to a full and independent public inquiry.

COSTS

18 The total cost of a strategy based on the collaborative deal outlined above can only be assessed in the light of negotiations. But I would want to see a significant reduction in the £4 billion over 20 years which an independent programme, or a collaborative effort which only absorbed foreign experience at the margin, would cost. To run down our programme and rely on a foreign license would on the face of it be cheaper, perhaps £1 billion or less over 20 years. But if in that period the likely need for fast reactors became pressing and policies were reversed, with the construction of a fast reactor and its fuel cycle beginning under licence, the costs would mount up sharply. Re-establishing a fast reactor capability, once dispersed, would be a long and costly exercise. The strategy I have recommended, based on the construction of a fast reactor in due course, would be a far more prudent course.

RECOMMENDATIONS

19 I seek the agreement of colleagues to the approach outlined above, including:-

(a) a strategy based on the intention to build a full-scale fast reactor, subject to safety and an inquiry, at a time to be decided later;

(b) a broad indication of policy in Parliament on the lines set out in paragraph 17;

(c) negotiations with the French and Germans to see whether a satisfactory collaborative deal can be obtained on the lines set out in paragraphs 12 to 15.

20 My proposals are set out more fully in the attached note.

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MINISTERIAL COMMITTEE ON ECONOMIC STRATEGY

FAST REACTOR POLICY

Memorandum by the Secretary of State for Energy

1 Now that our thermal reactor policy is settled, we need to develop our approach to the fast reactor.

NEED FOR FAST REACTOR

2 Fast reactors are potentially a major energy source, and the prospect is that both we and other industrialised countries will need to be able to build them in quantity in the first quarter of the next century as an important element in the diversification of energy supplies. The aim of fast reactor strategy must therefore be to ensure that we have access to the technology as and when we need it, and that we have the industrial experience and know-how in this country at that time to build them reliably and efficiently.

3 Fast reactors burn up the plutonium and depleted uranium produced in thermal reactor programmes, generate electricity from them and breed fresh fuel at the same time. Their high efficiency in the use of uranium could be very important if world uranium supplies come under pressure, particularly for a country like the UK which has negligible reserves of natural uranium but substantial stocks of depleted uranium. Our existing stocks used in fast reactors could have an energy content equivalent to 40,000 million tonnes of coal, comparable with our recoverable coal reserves.

4 We have had a fast reactor programme in the UK for some 25 years. A small 14MW reactor (DFR) came into operation at Dounreay in 1959, a prototype (PFR) of 250MW is now in operation there and our work on the fuel cycle is in the forefront of international technology. The logical next step would be to construct a commercial demonstration fast reactor (CDFR) of 1300MW, an issue which has been under consideration for some years. Expenditure is running at around £100 million p.a.

5 Other countries are developing fast reactors too. The French expect to bring Super Phenix, a 1200MW fast reactor, into operation in 1983 and may move to steady ordering from the mid 1980s. They are in collaboration with the Germans as principal partners, supported by Italy, (who in practice are playing a major role in the project, more prominent than the Germans), Holland and Belgium. The United States has deferred commercialisation of the fast reactor but maintains a very large programme running at around £300 million p.a. The Soviet Union brought a 600MW reactor coming into operation in April. Japan has a 300MW prototype under construction, and India a 15-18MW test reactor.

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6 Further details of programmes are in Annex A.

INTRODUCTION OF FAST REACTORS

7 Fast reactors are not yet economic and there is uncertainty about the timescale in which they will be introduced commercially.

8 Much depends on future uranium prices and on the likely capital costs of fully developed fast reactors and their fuel cycle. Their capital costs are at present much higher than those of thermal reactors, but the differential should decrease with experience. Moreover fast reactors are virtually independent of the cost of natural uranium and enrichment services, and this could be very important if uranium prices are forced up by demand or concerted action by suppliers.

9 The prospects for uranium supplies have been considered in a recent review led by my Department. This concluded that on conservative assumptions there is sufficient uranium in currently know 'low extraction cost' deposits to meet the lifetime requirements of all thermal reactors likely to be installed in the world by 2000. But thereafter, depending on the rate at which world nuclear programmes build up, we shall be moving into a period when uranium supplies will begin to constrain the rate of thermal power station ordering. Moreover, we cannot rule out the possibility of uranium supplies being disrupted earlier than forecast for political or other reasons, for instance environmental campaigns in supplying countries or a sudden surge in demand caused by a drop in world oil supplies.

10 The timescale for introducing fast reactors was explored in the recent International Fuel Cycle Evaluation (INFCE). The view of the UK Atomic Energy Authority (UKAEA) was that fast reactors could become economic between 1990 and2000 if uranium prices rose rapidly but that with a slower price increase this would be deferred to the following decade. Other delegations took widely differing views. The United States considered that fast reactors might not become economic until after 2025, whereas the French believed that they could be economic by 2000 even with no increases in uranium prices.

11 Given these factors and uncertainties, which are considered in greater detail in Annex B, it is reasonable to conclude that by the end of the century we shall need to be in a position where we can introduce fast reactors confidently and reliably as we need them, but with flexibility on the rate and scale of their introduction. The central issue therefore is how we can best put ourselves into that position, given also the long leadtimes involved in introducing the technology.

OPTIONS

12 There are many courses open to us.

13 We could decide to build a CDFR of our own design entirely independently of other countries, subject only to safety clearances and a wide-ranging inquiry. This would allow a single-minded effort. But we would be on our own if problems arose, and the risks would be very great.

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14 Or we could decide to build a fast reactor on a basis of collaboration with other countries. Sir John Hill, Chairman of the UKAEA, is recommending this course and believes that we should negotiate an arrangement with the French and Germans. His proposals are set out in more detail in Annex C. It is however very important to be clear what kind of collaboration is envisaged. There is in particular a great difference between a loose collaborative arrangement which is essentially an independent effort absorbing foreign technology at the margin and costing much the same as an independent effort; and an integrated arrangement which aims at a common design and a significant reduction in costs.

15 A major consideration in any strategy based on the construction of a fast reactor is the timing. The first priority at present is strengthening the nuclear industry and making a success of our thermal reactor strategy, and we must do nothing to divert effort or resources from it. We have also promised a wide-ranging inquiry if a CDFR is to be built here, and it would be wrong for such an inquiry to be held before the PWR inquiry, likely to start in 1982, is well out of the way. This means effectively that if we build a large fast reactor it will not begin construction before the second half of the 1980s. The UKAEA and the nuclear and electricity industries have advised me that this is the case.

16 We could alternatively decide to leave it to other countries to develop a commercial design of fast reactor and rely on them to make it available to us under licence on acceptable terms when we needed it, scaling down the UKAEA's programme accordingly, perhaps to a level where it would still assist in the introduction of fast reactors when the time came, or perhaps running down the programme completely.

17 These possibilities are analysed in more detail in Annex D. The analysis, which is based on advice from the UKAEA who have consulted other parties, is only illustrative and there are many variations on the different approaches. A major factor in assessing the options is their relative costs, considered below.

COSTS

18 Developing fast reactor technology is formidably expensive.

19 On present UKAEA estimates a strategy based on the early construction of a CDFR and its fuel cycle would cost £4 billion over the next 20 years at current prices. This represents an average of £200 million a year, roughly twice the present level of spend. Electricity revenues would offset part of this but there would be no prospect of the project being economic. And there would be financial and technical risks which could lead to delays and escalating costs. The UKAEA's figures are set out in detail in Table 1.

20 The UKAEA also estimate that a strategy based on international collaboration would cost nearly this amount. But inherent in their view is the assumption that our fast reactor would to a large extent be based on an independent design and supporting effort. It would be open to us to make it an objective of international collaboration that the overall costs of our strategy should be significantly reduced by a more closely integrated effort. This indeed is the course which I am proposing below.

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21 It would be much less costly to run down our programme partly or completely and to leave it to others, particularly the French, to develop commercial designs, relying on them to give us a licence when we needed it. The UKAEA's estimates suggest that the cost would be between £300 million and £1 billion over the next 20 years at current prices, depending on the extent to which their programme was scaled down (see Tables 2 and 3). But not all the difference between these figures and the cost of our present programme would accrue as savings; there would be substantial costs in redundancy payment, redeployment and decommissioning of facilities. More important, if it were decided in due course - as is **quite possible** - to re policies and build a fast reactor and its fuel cycle under foreign licence, the total costs over time might be very much nearer to the costs of a strategy based on international collaboration. And there would be a major inefficiency in first running down a fast reactor capability established over 25 years and then building it up again.

22 Relying on a foreign licence would also involve important disadvantages.

(a) The leadtimes involved in introducing a fast reactor technology, including the necessary industrial backing, are long. However much help our licensor gave us, we would need a period of years, perhaps a decade, perhaps more, depending on the circumstances, to get into a position where efficient series ordering was possible. The penalties if uranium supplies were tight could be high.

(b) it is not necessarily safe to assume that a foreign licence for fast reactors will be readily available on acceptable terms. In a position of urgency with perhaps only one or two potential licensors, our negotiating position would not be strong.

(c) we would be making no use of our considerable expertise in fast reactor technology. Re-establishing it once it was broken up would be a difficult and lengthy task.

23 None of this necessarily rules out the option of licensing fast reactors from abroad as a last resort. But it is not the most attractive option if we can obtain satisfactory collaborative arrangements on the lines proposed below.

PROPOSED APPROACH

24 We cannot take final decisions at this stage. It will take ti to negotiate and develop full proposals. But we need to give our nuclear and electricity industries guidance now and to establish clearly the strategy which we wish them to follow. I believe our approach in principle should be on the following lines.

25 Our policy should be based on the intention to construct a large fast reactor in this country at a time when it suits us. Ther are many issues that will need to be settled later, including the question of timing. But what we should make clear at this stage is

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our strategic decision to build a fast reactor at a suitable time so that we have the necessary know-how and experience as a long-term insurance for our energy supplies and will not have to rely on other countries to develop and supply the technology when we need it.

26 We ought not however to proceed in isolation from other countries. An independent CDFR programme would be enormously costly and risky and would give us a prototype reactor and fuel cycle which might not be replicable for later orders

A fast reactor based on collaboration would, if we secured the right arrangements, enable us to draw on the proven experience of our partners and to phase our programme with theirs so that our reactor represented one in a common series aiming to a progressive improvement in design and reliability and a reduction in cost.

27 I agree with the UKAEA and CEGB that the best prospects for collaboration at present lie in Europe, primarily with France and Germany who are already in partnership. Collaboration with the Americans would have considerable attraction, given in particular their experience with component development which is complementary to our own work on the PFR and on the fuel cycle. Indeed they have at high official and industrial levels expressed a real interest in investigating the scope for collaboration. But it is not clear that it is a real possibility. In particular President Carter has taken a firm stand against commercialisation of fast reactors. Even if policies changed after the Presidential election, the Americans might wish to proceed independently or seek a link with the French (which would isolate us); and even if they wanted to collaborate with us, there would be a risk of being unable to keep pace with them and ending up as minor and unequal partners.

28 I propose therefore that we should now seek to negotiate acceptable arrangements with the French and Germans. The proposals which the UKAEA have put forward to me will provide a basis for negotiation. But we need to set clear negotiating objectives and to obtain clarification and improvement in the terms on offer.

(a) The long-term aim of collaborative arrangements should be a design of fast reactor which can be built reliably, meet our safety standards and produce electricity at an acceptable cost.

(b) one of our major objectives in talking to the French should be closer integration, with joint designs and a jointly agreed programme in which our fast reactor should fit into a European series. Collaboration which simply continued our line of development and only absorbed French experience at the margin would be nearly as risky as an independent effort.

(c) we should use collaboration as a means of cutting down significantly on costs, for instance by coordinating investment in fuel cycle facilities and by cutting out duplication in research and development programmes.

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(d) we should seek to safeguard our industrial interests by formal agreements between manufacturers on the availability of component design and manufacturing know-how at an acceptable price.

(e) we should seek to reduce the downpayment of £50 million for which France are asking for access to their design information or, if we fail, we should at least ensure that what we obtain for the money is very clearly defined and that payments are only made in return for specific benefits provided by our partners as and when they occur. And there should be royalty arrangements which fairly reflect our contribution to the collaborative arrangements.

(f) we should negotiate parallel arrangements on the fast reactor fuel cycle, ensuring that our expertise in this area is fully reflected in the terms we obtain.

(g) we should ensure that we have a proper say in the licensing of technology to third countries.

(h) we should preserve our freedom of decision on the timing of construction of our fast reactor, a major consideration given the priority of our thermal reactor strategy and the present weakness of our nuclear industry.

IMPLICATIONS FOR THE UKAEA

29 Work on the fast reactor in one form or another represents around 60% of the UKAEA's net expenditure. The more we move away from the early construction of a CDFR of UK design, the more serious the implications will be for the work load of the UKAEA. In particular to the extent that we succeed in our objectives of achieving a common design, of cutting costs by eliminating duplication of research and development and of coordinating investment on the fast reactor fuel cycle, these could all be reflected in a reduction in the UKAEA's programme and in the strength of NNC's design team. We have to accept this. The right course is to decide what our policy objectives are and how we want to achieve them, and to consider the implications for the UKAEA thereafter. I intend to make it clear privately to Sir John Hill that I see no prospect of an independent effort on the CDFR without collaboration, though to make this generally known would of course undermine his negotiating position and must be ruled out.

NEXT STEPS

30 As a first step I propose to speak to my opposite numbers in France and Germany to make clear at political level our intention to build a large fast reactor in the UK in due course and our wish to do so in close collaboration with them provided that improved terms can be agreed. Thereafter I will ask the National Nuclear Corporation (NNC) and UKAEA to negotiate at an industrial level and report back to me when they judge that they have secured the best deal that they can get judged against the objectives set out above. We can then consider whether the proposals are acceptable.

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31 If we secure collaboration, the industries will need to prepare and put forward to us in due course detailed proposals covering:-

(a) the timing of construction of fast reactor seen in a European perspective;

(b) the design and cost of the reactor and any associated fuel cycle plant to be built here;

(c) the advice of the NII on safety aspects;

(d) the site where the reactor would be built;

(e) the organisation which would build it;

(f) arrangements for financing it.

32 If negotiations fail, we shall need to review the options which remain open to us, including possible collaboration with the United States or Japan or bilateral arrangements with the Germans on the fast reactor fuel cycle. Indeed we should maintain our contacts with the United States and Japan while our negotiations within Europe are proceeding.

FINANCIAL IMPLICATIONS

33 The estimated costs of various options are illustrated in Tables 1, 2 and 3. The figures have been provided by the UKAEA.

34 If we were to start construction of a CDFR in 1985, the UKAEA say they would need the following additional sums over and above their existing provisions to cover design work by the nuclear industry and additional development work in their own programme.

1981/82	1982/83	1983/84	£ million (1980 Survey Prices)
+6	+14	+20	

35 There are inevitable uncertainties about finance. But these figures (which have been included as additional bids in this year's Public Expenditure Survey) should be taken as a maximum. In particular:

(a) one of the aims of our negotiations with the French and Germans should be to achieve a reduction in costs on research and development (see paragraph 28c above);

(b) to the extent that construction of a CDFR and its fuel cycle is deferred beyond 1985, as is likely, the effect will be to defer capital spend and spread development effort over a longer period;

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(c) if contrary to my aims a downpayment has to be made to the French (see paragraph 28c), I would expect the UKAEA and the electricity supply industry to share it and the UKAEA to find their contribution from within their existing financial provisions. The cost of electricity supply industry's contribution is already provided for in the figures submitted for this year's nationalised industries investment and financing review.

36. I would therefore hope that the additional bids set out above can be reduced or eliminated and I propose that we should defer decisions on them until the outcome of negotiations is known. There are no other known extra costs in the PES period associated with the decision to enter into negotiations with the French.

PRESENTATION

37. We will not be in a position to make a major policy statement until negotiations have taken place and the scope for collaboration is much clearer. The French will however almost certainly express doubts about the seriousness of our commitment; and in order to help with the negotiations I would propose to make it clear in Parliament before the Summer Recess that we believe we much have access to foreign technology when we need it; that in order to do this we plan to build a fast reactor in this country in due course though constructi is unlikely to begin before 1985; and that we are exploring actively the possibility of international collaboration.

CONCLUSION

38. Our policy should be based on the intention to build a large fast reactor in this country at a time when it suits us and in close collaboration with other countries working in the field. Final decisions can only be taken when international negotiations are complete, when proposals have been fully worked up in the light of these negotiations and when a thorough public inquiry has been held. But this is the broad direction in which our policy should be moving.

STATUS OF LIQUID METAL FAST REACTOR TECHNICAL DEVELOPMENT IN THE UK AND WORLD-WIDE

(NOTE BY THE UKAEA)

Introduction

1. Interest in breeder reactors dates back to the earliest days of nuclear power research in the 1940s when the possibility of breeding was first recognised by pioneers in the nuclear field. One of the earliest steps was the construction of an experimental fast reactor called Clementine at the Los Alamos Scientific Laboratory. It was used from 1946 to 1953 to demonstrate the feasibility of operating a reactor with fast neutrons, plutonium fuel, and a liquid metal coolant. The Experimental Breeder Reactor No 1 (EBR-1) at Idaho produced the first nuclear-generated electric power in 1951, ie the first nuclear electricity in the world came from a fast reactor. In the UK work started in the early post-war period, and initial studies and experiments led to the design and construction of the Dounreay Fast Reactor which operated successfully for 18 years before being shut down in 1977.

2. The prototype Liquid Metal Fast Breeder Reactors (LMFBRs) now operating (PFR, Phenix, BN350 and BN600 together with the near-commercial LMFBRs being built (Super-Phenix) or designed (CDFR, SNR-2 and Super Phenix 2) and the test LMFBRS currently operating or near completion (EBR2, FFTF, PEC, JOYO, RAPSODIE), are all results of over thirty years of development work covering many topics and disciplines. There has been a substantial amount of international co-operation over the publication and exchange of data and experience for many topics over the years, although there is a growing reluctance to give away design and operating data as work reaches the commercial stage.

3. In this Annex, summaries of the developments in key areas are first given for the UK, followed by comments on the main activities in other countries with significant LMFBR programmes.

THE UK PROGRAMME

Reactor Physics

4. Early work was mainly directed towards compiling a comprehensive library of neutron cross-sections, using both direct measurements with neutrons of varying energies (differential data) and zero-energy mock-ups of power reactors (integral data). The ZEBRA reactor at Winfrith has operated since 1963, testing reactor physics data and calculational methods. The main task has largely been accomplished. Although there are improvements which justify more study, there is nothing in the reactor physics area with the potential to impede the building or operation of CDFR.

5. Heterogeneous cores are currently of interest as a possible future development: these are designs which include fertile blanket regions within the core. The aim is to improve breeding and therefore the overall economics, but the optimisation of these cores is not an easy task and is incomplete. Also the characteristics of heterogeneous cores is still being evaluated: some features are improved and some worsened when compared with standard cores.

Fuel Performance

6. To be economic, a burn-up of around 10% by heavy atoms in fuel pins is needed, and this has been achieved or nearly achieved in several countries. In the UK, development progressed from the metallic fuel used as the driver fuel in DFR to plutonium-containing oxide fuels for PFR and CDFR for which extensive pilot irradiations were mounted in DFR until 1977. In the course of this continuing long-term programme, a wide range of variables has been and is being explored (now in the PFR), including the pellet and particulate fuel forms, fuel density, fuel

rating, alternative cladding materials, methods of fuel pin support and alterna fuel manufacture and fuel fabrication routes. This experimental programme has demonstrated the fundamental robustness of the mixed oxide fuel element design. Tonne quantities of mixed oxide fuels have been produced and irradiated, with satisfactory results. Data obtained are enabling optimisations of choice of features for oxide fuel for CDFR, taking into account not only reactor performance considerations but also the requirements of the reprocessing and refabrication plants.

7. In order to verify the further durability of mixed oxide fuel assemblies, at the closure of DFR, fuel experiments with mixed uranium and plutonium oxides had reached peak burn-ups of over 20%. Defective fuel pins that had leaks in their stainless steel cladding were irradiated following development of the defects to a further 3% burn-up with little deterioration. During the final runs of DFR, the opportunity was taken of performing some experiments on fuel under conditions far removed from those of normal operation. These experiments have very usefully confirmed that fuel pins can survive for many hours with clad temperatures at the boiling point of the coolant (~1000°C).

8. PFR now provides the main test both for standard UK pins and for proposed variants. The results from RAPSODIE, PHENIX and other reactors have supported the UK experience. For commercial use, most countries currently propose to use mixed oxide fuel in stainless steel pins between 5 and 9 mm diameter, and all use sub-assemblies containing 200-300 pins. The main significant difference in fuel design lies in the choice of pin spacers, with a variety of grids and spiral wire wraps to choose from.

Irradiation Damage and the structural design of the reactor core

9. One main reason for operating prototype reactors is to uncover unsuspected development needs. For instance, two effects which are now generally recognised as of major significance in the design of large fast reactors were discovered during the experimental programme in DFR: fast neutron void swelling and irradiation creep of metals. Fast neutron induced void swelling is the swelling of core materials such as steels or nickel alloys due to the formation of voids under fast neutron irradiation. The swelling is troublesome in itself, but especially when gradients of neutron flux or of temperature across a component cause it to bend. Thermal creep is the deformation of structures under load due to the slow flowing of the material at high temperatures; the effect of fast neutron irradiation is to speed up the thermal creep in a manner similar to the raising of the temperature.

10. Materials suitable for withstanding the irradiation damage suffered within the core are being tested in the PFR, as are the calculational models and methods which are needed to predict the performance of core structural items. The design company (NPC) are likely to specify a mechanically restrained core for CDFR to cope with the bending or bowing of structural items.

Engineering and chemical engineering developments

11. LMFBR steam raising units (boilers) are generally accepted as presenting the major challenge in fast reactor design. Defects that have occurred in the boiler tubes of PFR and of BN-350 have necessitated repair work; but this has been of value in the experience it has provided of fast reactor station operation.

12. In the PFR steam generators, attention has been directed primarily to small leaks 25 tubes since October 1974. All leaks have been very small (typically a few grams of water per hour) and were detectable only by measurement of small resulting hydrogen concentrations using sensitive instruments. In all cases, controlled shutdowns of units were practicable well in advance of the leak reaching a pre-set reactor trip level. The repair procedure for such leaks is exactly the same as that on any other steam generator (ie to locate the affected tube and remove it

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rom service by plugging each end). It is important that this can be done with minimum effect on station operations, which requires ease of access to individual tubes and ability for the station to continue operation using the unaffected steam generators. Ability to do so has been confirmed on PFR. The proposed designs of steam generators for CDFR provide substantial improvements based on the experience gained on PFR. There has been very good operating experience with the boilers of PHENIX but their design is not regarded as typical of future commercial designs.

13. On a world-wide basis, there are several different designs of boiler being developed. The tendency in the UK is to favour U-tubes with small units because of the ease of access to tube bundles for repair and replacement, and to stay as close as practicable to PFR experience. France has made a bold step in choosing a large, complex hilical design for Super Phenix. There are also differences of opinion on whether to adopt one large heat exchanger per loop, giving economy of scale, or to choose a number of smaller units, making repairs easier and increasing the overall availability of the station.

14. In respect of sodium technology, the operation of many fast reactors and of test rigs over a long period have provided substantial experience in the handling, purification and instrumentation requirements of alkali metal coolants and knowledge of their properties relevant to fast reactor operation, such as compatibility with reactor materials, thermal performance, flow characteristics and radiation effects. Engineering development has been closely related to the design of the reactors. Notable examples have been coolant flow studies using air or water as working fluids to simulate the sodium coolant, complemented by tests of complete components in a hot sodium environment. For these purposes, extensive test rigs have been built; the two largest in the UK, the High Temperature Sodium Loop and the Sodium Components Test Rig, are being commissioned.

15. The UK materials development programme is planned to provide comprehensive data on the effect of a flowing sodium environment on the mechanical properties of the principal primary and secondary circuit materials. Equipment is being installed to carry out creep rupture and fatigue measurements for durations of up to 2 to 3 years in flowing sodium. Also the materials programme has yielded extensive information on mass transfer and corrosion aspects of both primary and secondary circuits.

Fuel Cycle

16. In parallel with reactor development, the need to develop and demonstrate the complete fast reactor fuel cycle has been recognised throughout the UK programme, first by building fuel fabrication and reprocessing plants at Dounreay to serve DFR, and then by provision of a fuel fabrication plant at Windscale to make fuel for PFR. More recently, the DFR reprocessing plant has been modified to reprocess PFR fuel. The fuel fabrication plant making mixed UO_2-PuO_2 pellet type fuel for PFR is one designed to include remote control concepts and so provide experience relevant to later large-scale production plants. This plant has been making fuel in the form of pellets for PFR for a number of years, while a pilot plant is nearing completion for testing an alternative fuel that consists of fuel spheres made by a gel precipitation process. These spheres are of two different diameters to facilitate close compaction. Use of this "wet" chemical process to make the fuel has potential to reduce radiation to plant staff. Thus data and experience of two fuel production routes will be obtained before finalising commercial plant design.

17. Development of vitrification processes for ultimate disposal of waste from thermal reactor fuel reprocessing is applicable to waste disposal for fast reactors, and consideration is being given to construction of a plant at Dounreay to process PFR waste.

Reactor Safety

18. Studies of the safety characteristics of fast reactors have been a feature of the UK programme, and in recent years there has been increasing international collaboration on development work relevant to safety that is proving to be very beneficial. The main issues of fast reactor safety are discussed in Annex VI, where the work carried out is described.

Operating Experience

19. The operation of a prototype reactor station inevitably leads to new development needs but also to increased confidence in areas where the design is proven. Experience from the operation of PFR, Phenix and BN-350 now covers over 16 operating years and lower power reactors have completed many more years. The three prototype reactors have been operated as power stations, undertaking operational manoeuvres, maintenance and repair procedures, refuelling work and other tasks typical of commercial installations, though experimental work has continued to be carried out at the same time in support of the R & D programme. The main lessons learned from their operation are:

(i) Liquid metal is to be seen as a relatively straightforward process material. Experience with coolant management including containment, maintenance of required purity and interaction with structural materials has been very satisfactory.

(ii) The stations have, as expected, been easy to control.

(iii) The reliability of the major components of the liquid metal circuits has been good. The overall availability of the reactor and primary circuit between scheduled shutdowns for refuelling exceeds 95% in all cases.

(iv) Fuel and component handling arrangements are satisfactory, though desirable design improvements have been identified.

(v) Maintenance operations that have had to be carried out on these stations have shown that the designs compare well with other systems in this respect. The inactive secondary circuits, the relatively small size of components and the capability for removal for out-of-pile repair are important in this context.

(vi) Though the availability of the primary circuit has been good, the performance of the reactors as reliable generating units has been vitiated by troubles with the steam plant and especially with the steam boilers.

20. For the UK a feature of operational experience with PFR has been the excellent performance of the primary and secondary sodium circuits. For these plant areas, major steps forward in size, complexity and operating conditions were taken from the limited experience in DFR and from development rigs. The major components operating in the sodium in PFR have performed well; the sodium pumps have operated continuously since 1973 with an availability close to 100%; the fuel handling machinery was used to load the first fuel charge and has performed subsequent reloading operations very satisfactorily. Operation of the reactor over the whole power range has been straightforward and radiation levels have been well below the authorised standards in all working areas. There have been no maintenance problems of any concern on sodium plant.

21. There have, however, been some features which have focussed attention on particular aspects of CDFR design, in particular emphasising the need to acquire further appreciation of thermal shock and thermal cycling conditions in sodium circuit components under normal and non-standard operating conditions.

Extrapolation to the Commercial Demonstration Fast Reactor, CDFR

22. The experience gained from operation of DFR and the construction of PFR established the UK as a world leader in fast reactor development. Since completion of PFR attention has been increasingly directed to the design and construction of a commercial size fast reactor station of about 1250 MW (E) based on this experience. A reference design incorporating the same basic ideas as the CFR was completed some years ago: in the absence of a decision to proceed with construction many possible improvements and modifications to the original concept have been studied. In most areas these have only served to confirm the correctness of the original choice: in some cases however improvements either to cost or performance have been possible. Some of the more critical components are the steam generators and in this case replacement units that use CDFR design features are being manufactured for installation and trial on PFR.

23. One important variation is the size and number of units used for these and other primary circuit components: a compromise has to be struck between the large units favoured on construction cost grounds and the desire to depart as little as possible from the unit size used on PFR so as to make the smallest possible extrapolation from direct PFR experience. In general the operating conditions for all these components are no more onerous than they are for PFR and indeed in many cases have been made rather less onerous by a reduction in the steam temperature from 540°C to 490°C. The fuel pins have the same rating in the two reactors and the general performance of fuel in PFR is expected to be repeated almost exactly in CDFR.

Summary

24. The UK has been an acknowledged world leader during most of the 30 year period during which the fast reactor has been extensively studied and developed. A good understanding of the technology of the complete station has been supplemented by experience gained from the UK's thermal reactor programme so that the UK is well placed for moving on to the construction of a commercial sized reactor.

OVERSEAS DEVELOPMENTS

25. Work in continental Western Europe is now proceeding under a series of collaborative agreements between France, Germany, Italy, Holland, and Belgium. Development is most advanced in France where work on fast reactors started in the 1960s with the test fast reactor Rapsodie at Cadarache. A prototype power reactor Phenix (250 MW (E) - pool-type) at Marcoule went critical in 1973 and the 1200 MW (E) Super Phenix at Creys Malville in France was begun in 1977 and is due for completion in 1982. It is being built as a joint venture with 5 European partners. In order to provide the necessary reprocessing facilities the COGEMA plant at Cap la Hague is to be expanded to cope with fuel from at least 3 Super Phenix-sized reactors.

26. Work on fast reactors in the Federal Republic of Germany has included participation in 2 collaborative projects, Super Phenix (as mentioned in the previous paragraph) and a prototype 300 MW (e), loop-type, fast reactor at Kalkar, SNR 300 (in collaboration with Holland and Belgium), currently under construction. It has also included the construction of the small experimental fast reactor , KNK II 20 MW(e). As part of the collaborative arrangements it was envisaged that a successor to SNR 300 to be called SNR 2 would be built in Germany.

27. Work at the national level in Italy is taking place at the national nuclear research centre at Brasimone where a 130 MW(t) fast reactor for the testing of fuel elements is under construction. Italy has been a junior partner in the French fast reactor project for many years, sharing in R & D and in component development. The Belgian nuclear industry's tentative plans for the introduction of fast reactors call for one station between the years 1995 and 2000 and 2 or 3 more between 2000 and 2025.

28. Other major fast reactor programmes are under way in the USA, the USSR, Japan and India. In the early 1970s the US Administration placed high priority on the LMFBR programme and the proposed construction of the 350 MW(e), loop-type, reactor (CRBR) at Clinch River, Tennessee, which was intended to demonstrate the fast reactor concept by 1980. More recently the present Administration have deferred the introduction of the use of plutonium by postponing reprocessing and the commercialisation of fast reactors. The future scope of the US LMFBR programme is still being debated, but the US continues to undertake a very substantial fast reactor programme; the US Department of Energy's budget for 1980 shows $590m (£300m) for such work and a large loop-type fast test reactor (Fast Flux Test Facility, FFTF) of 400 MW(t) became operational in February 1980 at Hanford, Washington. The large expenditures on fast reactors and on thermal reactors (Civil and Naval) has given a wide range of expertise to many organisations and individuals. This gives the USA considerable ability to catch up on fast reactors whenever their need for it becomes widely accepted.

29. The USSR have a strong commitment to fast reactors. Their first major experimental fast reactor, the BR 5 of 5 MW(e) was built at Obninsk some 20 years ago and is still operational. This was followed by a larger reactor, BOR 60, and a prototype reactor, loop-type (BN 350) at Shevchenko on the Caspian Sea which came into operation in 1973. BN 350 is designed to purify 120,000 tons of water per day as well as to generate 150 MW(e) of electricity. The first commercial-scale fast reactor to be built in the USSR, BN 600 (600 MW(e) pool-type) commenced operation in April 1980 at Beloyarsk. There are plans for a 1600 MW(e), pool-type fast reactor for completion in 1989 (work would start in about 1982), also at Beloyarsk; and the Russians confidently expect the majority of their nuclear programmes after 1990 to consist of fast reactors.

30. In 1968 the Japanese Government announced a plan for the development of the fast reactor which would lead to the construction of a prototype reactor with the aim of reaching the commercial stage in the second half of the 1980s. This plan involved the construction of a 100 MW(t) experimental reactor (JOYO) for use as a fuel and materials testing facility and this went critical in April 1977. The next step is the design and construction of a 300 MW(e), loop-type, prototype (MONJU) by 1986 and this is intended to demonstrate the feasibility and reliability of the system. Research and development work for the necessary fuel cycle activities for the demonstration fast reactor that will follow MONJU is already under way.

31. Fast reactor research and development work in India is undertaken at the Reactor Research Centre near Madras where a 15-18 MW(e) fast breeder test reactor and other support facilities are being constructed as part of the long range objective of thorium utilisation. It is expected that the test reactor will be operating in 1981 as a test-bed for experiments in connection with a larger reactor. India's declared intention is to have fast reactors in operation by the beginning of the next century.

CONCLUSIONS

32. The development of fast reactors is unique in that nearly all the leading industrial countries have conducted major programmes in parallel over the past decades, reflecting the importance attached to their potential for reducing dependence on natural uranium supplies. In the UK the successful experience with the experimental Dounreay Fast Reactor from 1959 to 1977 led to the construction of the 250 MW(e) Prototype Fast Reactor, pool-type, also at Dounreay which has been in operation since 1974. Parallel with the reactor programme, the UK has had a major programme of supporting research and development, and has made particular progress with fuel cycle work when compared with other countries. A plant to reprocess the spent fuel arising from PFR has just been commissioned, and this is the first of its type in the world. On the basis of this experience it is possible to approach with confidence the next stage of fast reactor development, involving a commercial-sized fast reactor.

THE NEED FOR THE FAST REACTOR

1. The fast reactor is by far the most highly developed new energy technology with the capability of making a major contribution to UK energy supplies in the first quarter of the next century, when fossil fuel supplies are expected to be increasingly scarce and uncertain and when the availability or uranium supplies for additional thermal reactor programmes may also be in doubt.

Uranium Supply and Demand

2. The future prospects for uranium supply and demand in the non communist world were studied in the recent international Nuclear Fuel Cycle Evaluation (INFCE)(see Table A). INFCE emphasised the uncertainties in predicting the growth of demand for nuclear generating capacity, and the levels of uranium production possible, over the next fifty years.

3. INFCE produced a high and low projection of growth in nuclear generating capacity in the non communist world. The low case projection for 1985 was 245 GW, rising to 850 GW by 2000 and to 1800 GW by 2025. The high case projection for 1985 was 275 GW rising to 1200 GW by 2000 and to 3900 GW by 2025. Developments in nuclear programmes since these projections were made suggest that, at least for the year 2000, the low case should be regarded as the more realistic.

4. INFCE made a number of projections of annual uranium requirements. These depend not only on growth in nuclear capacity but also on the reactors and fuel cycles used in the non communist world. Assuming low growth, and the widespread use of the LWR without reprocessing - the present standard practice - uranium requirements were projected to rise from 29000 tes/yr in 1980 to 135000 tes/yr in 2000, and to 260,000 tes/yr in 2025.

5. Currently known uranium resources total 5 million tonnes. This is at extraction costs excluding exploration costs and profit)$130/kg, compared with present long term contract prices of around $45-70/KG . International studies have identified a further 6.6 to 14.8 MT of speculative resources, but production from the majority of these is not likely to be possible until after 2025. INFCEs projections of maximum annual production from known resources rise from 50,000 tcs in 1980 to a peak of 120,000 tcs in 1995, falling to 35,000 tcs in 2025. Estimates of maximum production from currently speculative resources are uncertain. [

] An optimistic projection by the US Department of Energy, used in INFCE, suggested that total annual production could be between 135 and 175,000 tcs in 2000 rising to a peak of 140-300,000 tcs in 2025.

6. INFCE's conclusions on uranium supply and demand were:

(a) annual uranium requirements for the low growth projection, assuming the use of LWRs without reprocessing, would exceed annual production from known resources by 2000;

(b) the high estimates of production from speculative uranium resources would support nuclear growth on this basis until 2025, but the low estimates of production would place constraints on the use of LWRs without reprocessing by 2005-2010.

7. INFCE concluded that the lessons to be learnt were

(a) there was a pressing need for increased uranium exploration and development ventures; and

(b) many countries would wish to develop or have available advanced reactor types, such as the fast reactor, for introduction early in the next century. Concerns about the political, not just the geological, availability of uranium would weigh heavily in leading countries to such conclusions (see below).

8. There is no prospect of uranium resources being found in the UK that would make a significant contribution to our thermal reactor programme, and some 80% of the World's known uranium resources are in North America, Africa, or Australia. So we are likely to remain dependent on the policies of uranium exporting countries for our supplies. The 1977 Canadian embargo on uranium exports, opposition in Australia to uranium mining from the Labour Party and trade unions, and the continuing political instability of some African states, are illustrations of the circumstances which might cause supply interruptions.

Fast Reactor Technology

9. Existing thermal reactors such as AGR and PWR operate mainly on the isotope U_{235} which constitutes less than 1% of natural uranium.

10. The fast reactor is initially fuelled by plutonium derived as a by-product of thermal reactors. But it also has the ability to 'breed' additional plutonium from U_{238}, the isotope which makes up the other 99% of natural uranium. Through repeated cycles of fuel reprocessing the fast reactor is eventually able to extract 50 or 60 times as much energy from a given quantity of natural uranium as existing thermal reactors.

11. The fast reactor now has more than twenty years of development behind it in the UK and continental Europe, Japan, the USA, and Russia, are all investing heavily in its technology.

Other Nuclear Technologies

12. Some improvements in the uranium efficiency of PWRs is believed to be possible, for instance by re-cycling uranium and plutonium and improvements in technology. But even on optimistic assumptions the potential total saving is probably limited to 40% of uranium requirements. Similar fuel cycles used in CANDU reactors could increase these savings by 10%, but the timescale may be long.

13. A nuclear fuel cycle based on thorium rather than plutonium is also believed to have potential but there has not been the same international commitment to this technology, its costs are less certain, and it is thought that commercial development would take at least 25 years. INFCE did not see any benefit from the point of view of proliferation in the Thorium cycle.

14. Nuclear fusion is at an even earlier stage of development and, assuming that it proves to be practicable as a source of electricity, it is not expected that it could be commercialised until the second quarter of the next century.

Fast Reactor Economics

15. The fast reactor is not an economic proposition at present. It has a lower fuel cycle cost than LWRs because it uses very little uranium and requires no enrichment. But at present these savings would be outweighed by its larger capital costs, which are mainly the consequence of its larger nuclear steam supply system.

16. The question of when fast reactors will become economic depends on how fast its capital costs can be brought down and on how fast uranium prices rise. The question is complicated by the possibility that without the widespread introduction of fast reactors the rate of increase in uranium prices could be higher than would otherwise be the case.

17. INFCE did however conclude that fast reactor capital costs would decrease with increasing experience, with the scaling up of manufacturing capacity and with the construction of a number of reactors. INFCE estimated that the capital cost of the first generation fast reactors could be 1.5 to 2 times that of present LWRs. Estimates of the uranium price necessary for such a reactor to compete with present LWRs vary from \$250 to 500/kg compared with present spot prices of around \$100/kg. INFCEs estimate of the ultimate capital cost ratio possible for fast reactors compared with LWRS was between 1.1 to 1.3, though the Americans considered that it could be higher than this. Such a reactor would compete with LWRs at uranium prices of between \$100 - 200/kg.

18. A variety of views were however expressed by the different delegates in INFCE on when the fast reactors savings on uranium and fuel cycle costs would outweigh its extra capital costs (see table B). The French believe that fast reactors will become economic by the year 2000 even with no increase in uranium prices. They acknowledge that the full scale fast reactor that they now have under construction, Super Phenix, will be much more costly than a PWR but they expect to reduce the margin on the next station, to be ordered in 1983, to 30% or less. In contrast the Americans, who have uranium sources of their own, and who have a political objective of delaying commercialisation of the fast reactor, consider that it will not be economic until after 2025.

19. The UK view was that fast reactors could become economic around 2000 if uranium prices rose rapidly at or soon after that date, but that slower or later price increases would delay commercial breakeven until the following decade. Price increases and their timing will depend on resources discovery and exploitation, on economic and energy demand growth rates, and on political factors, and are therefore difficult to predict with any confidence.

20. The way in which a country's perceptions of movements in the extra cost - or premium - of generating electricity from fast reactors, and in the price of uranium, affect its perceptions of the economics of different fuel cycles can be demonstrated diagrammatically. Figure 1 shows how the once through cycle in LWRs is economic at low uranium prices and when the "fast reactor premium" is high. It shows how recycling plutonium into LWRs is economic when fast reactors are expensive and uranium prices high. And it shows how fast reactors become economic when their capital costs are reduced and uranium prices rise. Line A on the diagram represents the perceptions of a country that believes that fast reactor capital costs will fall quickly and that uranium prices will rise slowly. Line B is a country that believes that fast reactor capital costs will fall slowly and that uranium prices will rise fast. The problem in determining the moment when fast reactors will become economic is the problem of determining the correct position of these lines.

Rate of Introduction

21. It may take as long as 20 or 30 years for a fast reactor to 'breed' enough plutonium, in addition to its own requirements, to provide the initial fuel for a second reactor and this 'doubling time' can be a constraint on the rate at which fast reactors are introduced.

22. But because of our early start with nuclear power and the high efficiency of Magnox reactors in generating plutonium the UK is well placed, in terms of plutoniu supply, to launch a fast reactor programme.

23. For instance, the report of the Windscale inquiry concluded that the plutonium from our Magnox reactors alone would be sufficient to allow the introduction of 10 of fast reactors. The rate of introduction thereafter would depend on the rate of reprocessing of AGR, PWR, and fast reactor fuel, but it is clear that a substantial programme could be supported.

24. If all our existing reserves of depleted uranium were eventually converted to plutonium and used as fuel for fast reactors the energy produced would be equivalent to some 40,000 million tonnes of coal. In other words a UK fast reactor programme would be entirely independent of new uranium imports although, depending on the growth of electricity demand and fast reactor installation, fast reactors and thermal reactors might need to be installed in parallel in the early years of the next century.

25. Conclusions
The only prudent assumption, on the evidence now available, is that the UK will need the fast reactor at some time in the first quarter of the next century as a major element in the diversification of our energy supply.

26 June 1980

URANIUM SUPPLY AND DEMAND (Non Communist World)

	Nuclear capacity [a]	Annual Uranium Requirements [b]	Maximum Annual Uranium Production from known Resources	Maximum Annual Uranium Production from known & speculative resources [c]
1980	144 GW	29 (000 tonnes)	50 (000 tonnes)	50 (000 tonnes)
1990	373	66	95	95
2000	850	135	115	138–177
2015	1450	220	70	165–285
2025	1800	260	40	142–305

(a) INFCE low growth projection

(b) LWRs without reprocessing (Once through cycle)

(c) US Department of Energy Model

FAST REACTOR LIFETIME GENERATING COST BREAK-EVEN DATES (INFCE)

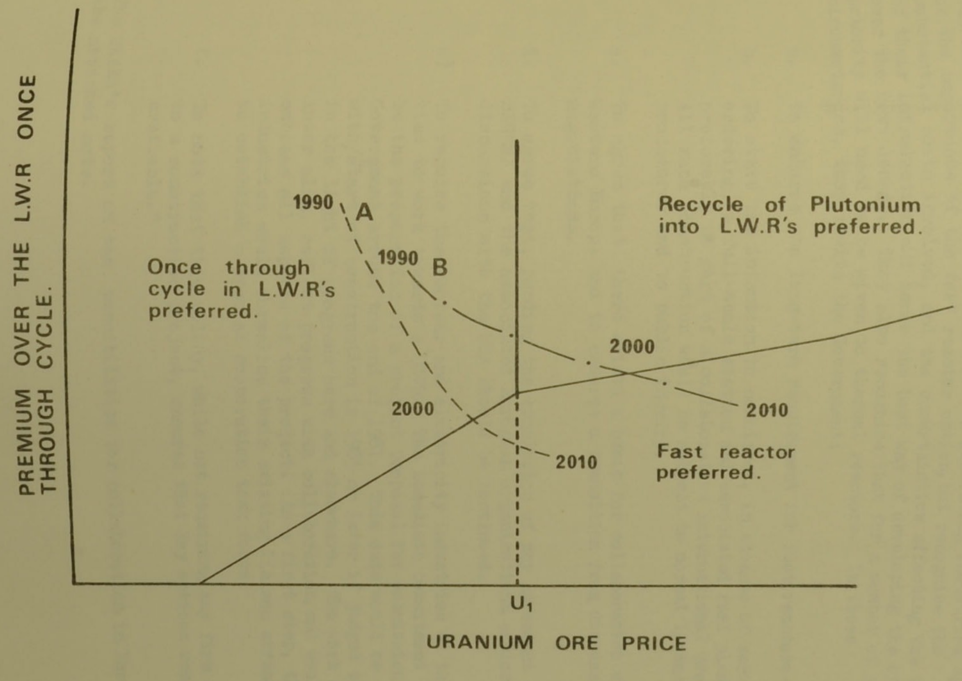
Country	Future Uranium Price Scenario	
	Low [a]	High [b]
Belgium	About 2000	1990–2000
Canada	–	–
France	1990–1995*	1985–1990
FRG	About 2000	About 2000
Japan	About 2000	About 2000
Netherlands	1995–2010	1985–1995
UK [c]	2000–2010	1990–2000
USA	After 2025	2010–2025
CEC	2000–2010	About 2000

*France considered a 3rd scenario in which uranium price remains constant at $40/lb U_3O_8. In this case the fast reactor breaks even in the late 1990s.

[a] Rate of increase = 2% per annum

[b] Rate of increase = 5% per annum

[c] UKAEA indicative position



U_1 = Uranium price at which it becomes more economic to recycle plutonium into L.W.R's than to follow the once through cycle.

FIG 1

ANNEX C

THE PROPOSALS PUT FORWARD BY THE UKAEA

1. Sir John Hill, chairman of the UKAEA has put forward the following advice, with the agreement of those concerned in the nuclear and electricity supply industries.

> "In summary, the nuclear and electricity generating industries agree on the importance of the fast reactor option, but recognise the substantial costs involved, and the uncertainties affecting the timing of their introduction and hence the best way of developing the option over the next decade. They also recognise that for a number of years priority will need to be given to thermal reactors. In these circumstances, they invite the Government:
>
> a. To endorse the long-term requirement for fast reactors.
>
> b. To state the intention to construct, in advance of series ordering, a full-scale station and associated fuel plants, preferably as part of a collaborative international programme. All such construction would be subject to normal licensing procedures and to public inquiry.
>
> c. To agree that there exists a basis for collaboration with Western Europe and to endorse a transition from discussions to negotiations.
>
> d. To agree that, pending the conclusion of any agreement with SERENA and the associated European organisations, exploratory discussions with the USA should be continued.
>
> e) To require the nuclear and electricity industries at the same time to work towards a CDFR. The immediate commitment would be the preparation of a project proposal for submission to Government around the end of 1981. This date would be consistent with a start of construction in 1985 or later if judged appropriate in the light of progress here and elsewhere. The work should, inter alia, reflect progress with collaboration, and would embrace all aspects of the project. As a first step, the industries would formalise their existing liaison arrangements to establish a special cooperation task force.
>
> f. To note that this policy, while not requiring any firm commitment to a construction project, ensures that key options remain available."

2. The UKAEA's report on the possibilities for collaboration in Europe is set out in the attached note.

D/Energy
26 June 1980.

EXTRACT FROM REPORT ON COLLABORATION BY THE UKAEA

In 1977 a series of agreements was signed between Germany (supported by Belgium and Holland) and France (supported by Italy) which brought together the fast reactor programmes of those two groups of countries while retaining diversification in design approaches for the present. A special organisation, SERENA, was established by the parties and mandated to license their fast reactor technology to design and construction companies. Co-operation is now extensive on reactor R & D and design but progress on fuel cycle aspects is delayed by an insistence by the French that no fast reactor fuel reprocessing co-operation may start until problems on thermal fuel reprocessing are settled.

The talks between the UK and the SERENA partners have covered the overall co-operation terms, co-operation on design, and co-operation on R & D. The initial UK approach was to join SERENA but as the French have insisted that this is not possible at present, the UK organisations have proposed a special UKAEA-NPC organisation, FASTEC, to interact with SERENA and represent British interests. There have also been talks between UKAEA/BNFL and CEA/COGEMA (France) on the fuel cycle, aimed at a parallel agreement. It is intended to bring German organisations into these talks later.

From a series of discussions it is now believed that a set of agreements can be negotiated on the following lines:-

(a) A collection of interdependent agreements with Governmental approval between SERENA and FASTEC, between the R & D organisations, between the reactor design organisations and between fuel cycle organisations, and in due course between component manufacturers.

(b) The SERENA-FASTEC agreement would cover the cross-licensing of all information and provide for the collection and sharing of royalties from reactor construction licensees.

(c) The R & D agreement would cover the co-ordination of R & D programmes and use of facilities and the exchange of all relevent information. The UK would have equal representation and rights with those of France or of Germany on the management of the co-operation and participation in the specialist working groups.

(d) The design co-operation agreement would have as the ultimate objective the achievement of a common design of reactor (suitable for construction in appropriate versions, firstly in Europe and later anywhere in the world). The more immediate objective would be greater concentration on practical issues of real projects. There would be exchange of present and future system design, construction and commissioning information, exchanges of staff and assistance with design problems.

(e) The fuel cycle agreement (limited to France temporarily) would cover exchange of all fuel cycle information, co-ordination of R & D and perhaps also co-ordination of investment plans for plants. The UK would have equal rights with France.

(f) It will be highly desirable but not easy to create a comprehensive set of formal agreements between the component manufacturers because of the know-how which is incorporated in the detailed manufacturing design and the manufacturing operations which may depend heavily on the pre-existing knowledge of these companies. Whether or not there is a set of formal agreements between the component manufacturers it is clearly intended that every effort will be made to ensure availability of component design and manufacturing know-how to the co-operating countries.

In the discussion of these agreements, the need for the approval of the Governments concerned has been stressed. This will involve consideration of broader issues, including non-proliferation.

The two sides have exchanged drafts of Memoranda of Understanding covering the whole co-operation. The more recent from the SERENA partners has been discussed in meetings and correspondence over the last few weeks. It specifically includes the points listed as 5 (a) (b) (c) (d) and (f) above, omitting (e) since the fuel cycle is not at present discussed with the Germans present.

It has not been possible to discuss fuel cycle collaboration on the same basis with the SERENA partners. Bilateral discussions have been held with the French, but progress has been slow because of a French preference for deferring exploration of possible terms in depth until the shape of agreements in the reactor field was clear. There has nevertheless been progress on the type of fuel cycle collaboration and the French have now accepted UK insistence that the reactor and fuel aspects are to be taken as a comprehensive package for collaboration.

Since the remit of the UK team did not extend to negotiating an agreement, it has been understood that any documents exchanged or verbal statements made have not been binding. It is not posisble to state what can be achieved when we can negotiate formally, though the SERENA partners have reserved the right to regard the present suggested framework as a package, so that changes in one part could invite balancing changes in another. The main features of the present proposals are:-

(a) The UK would receive all design construction and commissioning information on Super Phénix 1 (which is due to be brought on power around the end of 1983). When the full package is negotiated, the UK could have access, through the participation of some of its staff, to the design work for Super Phénix 2 to be carried out over the next two years for Electricité de France and to be completed early in 1982. In turn the UK design work will be made available to the French and German teams.*

(b) The UK would take part in full collaboration with the French and German (and other) organisations associated with SERENA on R & D programmes on the basis of continuation of approximately the current levels of expenditure in the three main countries. The UK would join the existing Liaison Committee to co-ordinate the programmes.

(c) The control of the use of the joint pool of information will be as follows. Prior to the conclusion of the agreement between SERENA and FASTEC the parties will produce an agreed short list of countries in which SERENA is authorised to negotiate licence agreements if a willing licensee can be found. In such countries FASTEC will be consulted on the choice of licensee and terms of the licence but will not have a veto. For all countries not on the list a basically similar arrangement will apply, except that FASTEC will be in a position to veto the licensing of a company within any such country.

(d) Royalties are one of the two parts of the agreement involving financial terms. Future royalties arising from construction of fast reactors by partners in partner countries will in principle be shared but the UK will have to 'qualify' for a share by building at least one full-scale reactor. The sharing will, in principle, be linked to the relative amount of construction of fast reactors in each country over the next 20 to 30 years; devising a fair formula, and predicting the outcome, will be difficult. On the question of royalty income from other countries e.g. the USA, or from construction of fast reactors by the partners in those countries, SERENA has conceded that the improvement in the negotiating position which will result if the UK joins France and Germany is such that the UK should have a 'fair share' of this income once agreement is reached.

(e) There will be an entrance fee to reflect the more advanced status of the French programme. It has been attempted in discussions to ensure that having paid this fee, the UK should be treated, as far as possible, as an equal partner. The SERENA partners have proposed that the fee be related to the extra costs of the Super Phenix 1 demonstration reactor compared with a PWR and have asked that the UK meet 15% of such extra costs as its entrance fee; the consequent payment would be £50 m, which the SERENA partners would (ad referendum) be prepared to see spread over 5 years.

A collaborative arrangement of the type envisated will not be easy to implement because it will require some co-ordination of objectives between the UK Generating Boards and EdF; parallel inter-utility agreements, consistent with the SERENA/FASTEC agreement, would be needed. Co-ordination will also be necessary between the NII and the corresponding institutions in France and Germany. The extent to which safety standards and operating requirements can be harmonised is not clear. Also the effect on costs in the UK and the pattern of supporting research and development will only be clear after full collaboration has started. The optimum timing of a UK demonstration reactor will have to be further considered and possibly adjusted to make it form part of a concerted 'European' series. This will depend on the degree of integration of design and objectives that in the event takes place in the light of progress here and in France. Despite these uncertainties, the overall judgement must be that if financial terms broadly similar to those which have been offered are acceptable to the UK it will be possible to negotiate a working collaboration with the French and Germans which will substantially increase the certainty with which the breeder reactor can be demonstrated and converted to a commercial application.

It may be noted that when SERENA was established by the French and Germans a few years ago it was in the context of a French belief that the Super Phénix 1 reactor, when built, would be a commercial prototype for which other countries would wish to take a licence. Events have shown that the Super Phenix 1 design, constructed on a once-off basis, is quite expensive, and NOVATOME, in co-operation with Electricité de France, are to engage for the next 2 years in the detailed design and preparation of a tender for Super Phénix 2 which is stated to be aimed at "near-commercial prices". It has therefore been necessary in discussions to persuade the SERENA partners that the UK did not wish to construct a copy of the Super Phénix 1 reactor under licence but rather, subject to a satisfactory agreement, to work with the French and Germans to evolve a European-based design of reactor and probably a European fuel cycle, so that in both cases economies of series production or of scale could be secured.

ANNEX D

ANALYSIS OF FAST REACTOR OPTIONS

1. This analysis of options is based on material and figures provided by the UKAEA. The options are illustrative only. In particular international collaboration could take many forms, ranging from a loose exchange of information to a close integrated effort, and the costs and implications would differ greatly. Option 2 must be seen in this light.

2. The options considered are:

OPTION 1 – Independent Programme: We could decide to proceed on our own with a CDFR and its fuel cycle of UK design, subject to safety clearances and the outcome of the full public inquiry which has been promised.

OPTION 2 – International collaboration: We could seek to build a large fast reactor, subject to safety clearances and a full inquiry, on a basis of collaboration with either France and Germany (who are already in partnership) or the United States. This option covers a variety of possibilities: see previous paragraph.

OPTION 3 – Holding programme: We could formally defer any decision to build a commercial fast reactor until the need for fast reactors is more firmly established and maintain a holding programme in the meantime: that is, maintain a significant programme of research and development including PFR and associated fuel plants, monitor overseas programmes and possibly negotiate arrangements to acquire foreign technology under licence if and when we need it in return for our present knowhow.

OPTION 4 – Withdraw: We could decide to rely entirely on being able to get an overseas licence for fast reactor technology if and when we need it, and run down our present programme including PFR and Dounreay.

3. All costs in this Annex are at 31 March 1980 prices.

OPTION 1: AN INDEPENDENT CDFR

1. We could decide to proceed on our own with a CDFR of UK design. The Government would authorise the nuclear industry to prepare for a wide-ranging public inquiry, and declare their intention that subject to safety clearances and the outcome of the inquiry construction of a CDFR would start at a date to be settled in due course.

OBJECTIVE

2. The aim would be establish and prove our own design of commercial fast reactor, making full use of the expertise which has been developed in this country over the last 25 years and allowing our nuclear industry to proceed single-mindedly with the project, unconstrained by the involvement of other countries.

TIMING

3. The UKAEA (who favour international collaboration: see option 2) have recommended that work should be based on a planning assumption of a CDFR starting construction in 1985 or as early as is reasonably practicable thereafter. It is not possible to be more precise than this at present. In particular:

a. <u>need to avoid clash with PWR inquiry</u>. The UKAEA consider that it would be undesirable for two major inquiries on nuclear power development to be held concurrently, and the CEGB would wish, if possible, to have the PWR inquiry first. Given the importance of the PWR option this is right, but it means that a CDFR inquiry could not start before 1983 or 1984. A construction date of 1985 for a CDFR is very tight.

b. <u>demands on the NII</u>. It is unlikely that the NII could manage a quicker timetable without more resources. They have carried out work on the commercial fast reactor in the past, and indeed said publicly over three years ago that given a successful outcome to development work, there should be no reason why a commercial fast reactor could not be made safe enough to be licensed. But they have since ceased their work because of a shortage of recources, and they would not be able to handle two major inquiries simultaneously.

COSTS

4. The UKAEA estimate that the total cost to the end of the century of a fast reactor strategy based on building a CDFR would be of the order of £4 billion, comprising:

a. <u>the lead station</u> itself estimated at £1620 million (including capital and operating costs and interest during construction, but no post-contract contingency);

b. <u>the fuel cycle</u> which could cost £1050 million (including fuel fabrication and reprocessing plants, research and development, capital and operating costs and interest during construction, but no post-contract contingency);

c. research and development in support of the CDFR by the UKAEA and the nuclear industry of £805 million;

d. continued operation of the PFR and its fuel cycle at a cost of £485 million (net of electricity revenues for PFR).

5. These estimates are set out in detail in Table 1. Inevitably they are very tentative, particularly for the later years. Factors which would affect the costs include:

a. post-contract contingency allowances. The estimates include a 20% contingency on the CDFR itself and a 17½% contingency on the fuel fabrication and reprocessing plants, but no allowance for post-contract contingencies. It is customary for the CEGB to include 17½% for this in their quoted thermal reactor costs, which if adopted for CDFR would add £250 million to the estimate.

b. transmission costs. No provision has been included for the substantial new transmission connections likely to be needed if the CDFR is at a remote site. The precise cost would depend on the site chosen and other factors. If it were Dounreay, the total transmission cost could on pessimistic assumptions be up to £250 million.

c. closure of PFR. If the CDFR were at Dounreay and it were decided to close PFR, say, six years early in 1990 to release commissioning effort for CDFR, a saving of some £120 million might be made, plus a possible further £40 million on capital plant associated with PFR.

d. timing of CDFR. If construction of the CDFR were delayed to 1987 or 1989, capital expenditure would be deferred, development work would be spread over a longer period and expenditure in the early years might be reduced slightly. But the overall effect would be to increase the cost of the project because there would be an extra two or four years of expenditure of around £50 million per annum before the project began.

e. research and development. The estimates in table 1 reflect the research and development needed to support the CDFR. They do not include any allowance for a continuing research programme in support of later fast reactors or the further development of the fast reactor fuel cycle. This might cost an additional £10-20 million each year.

6. Equivalent PWR. How the costs of a CDFR would be shared between central Government and the Generating Boards would be a matter for negotiation. Prima faci the Boards should at least bear the cost of providing equivalent generating capacity by means of a PWR on the same timescale. Table 1 sets out these costs on a similar basis, which the UKAEA estimate would come to £1200 million.

ADVANTAGES

7. Building an independent CDFR would follow the logic of our fast reactor programme so far and would give us secure access to the technology without outside constraints. There would be no royalties to other countries, no need to consult about fast reactor exports, no problem of adapting other designs to our own safety standards, no question of transferring technology from abroad to our own manufacturers, no diversion of effort into arrangements for co-ordination. It would set our nuclear industry a clear single-minded challenge for which to plan and recruit. The fast reactor would become a major asset in our long-term energy strategy if world uranium supplies became tight and expensive.

DISADVANTAGES

8. The costs would, however, be very great: see paragraphs 4 to 6.

9. There would moreover be risks, both technical and financial. However much design and development work preceded construction, experience suggests that a prototype involving high technology like the CDFR would raise new technical and engineering problems, that these might lead to delays and that the costs would escalate. With an independent effort we would have to solve the problems and underwrite the costs on our own. The potential burden on our economic and industrial resources would be great.

10. Once begun it would also be a major industrial commitment with little room for flexibility, however world uranium supplies turned out. Assuming that the inquiry and safety clearances were satisfactorily completed, there would inevitably be strong pressure to proceed at once to construction of the CDFR so as not to lose momentum. Similarly, once the CDFR was completed the industrial logic would be to follow on at once with further fast reactors orders as a prelude to series ordering, in order to maintain the industrial workloal, to keep teams together and facilities occupied, and to build on the expertise which had been gained at such cost.

11. Design and construction of an early independent CDFR would be a major demand on the management and other resources of our nuclear industry at a time when their first priority should be the efficient construction of thermal nuclear power station, in itself a considerable challenge given the industry's present weakness. It would also put a great strain on the NII (see para 3(b)).

12. Finally, we would be starting a long way behind the French who aim to bring a 1300MW fast reactor, Super Phenix, into operation in 1983 and are considering a move to steady ordering from the mid-1980s onwards. And though we would be ahead of the Americans when we begun, we could fall behind them if they were to decide to develop fast reactors given the enormous sums of money which they are spending on the technology.

OPTION 2: FAST REACTOR BASED ON INTERNATIONAL COLLABORATION

1. We could seek to build a large fast reactor, subject to safety clearances and a full inquiry, on a basis of collaboration with either France and Germany (who already collaborate) or the United States.

2. The UKAEA and other parties have recommended collaboration with France and Germany: see Annex C.

OBJECTIVE

3. International co-operation could take many forms, from a limited exchange of information of the kind we already have with several countries at present to a closely integrated partnership.

4. The general aim assumed here is that we want to secure access to the technology by building a fast reactor in the UK, but to avoid or reduce the costs and risks of an independent programme by sharing experience, knowhow and facilities and other joint arrangements.

5. Success in meeting this aim will depend on a number of factors including the extent to which all partners are committed to this arrangement. Another major consideration is the extent to which collaboration represents a departure from an independent programme in which foreign experience is only absorbed at the margin, and becomes a closely integrated partnership.

POSSIBLE PARTNERS: THE UNITED STATES

6. The United States spend far more on fast reactor research and development than any European country, including France, and their work in some areas such as component development and test facilities is unequalled. But they lack the experience which we and the French have gained from our prototype reactors and fuel cycle work.

7. In many respects, the UK and US fast reactor programmes are complementary, and Anglo/American collaboration on the fast reactor could be advantageous. Exploratory discussions between the UKAEA and US utilities last year raised hopes of collaboration on the launching, construction and operation of four or five large fast reactors and associated fuel cycle services, with the first fast reactor being built in the UK, and US utilities bearing a substantial proportion of the cost.

8. There are, however, major uncertainties.

9. First, President Carter has repeatedly asserted his determination to defer the commercialisation of the fast reactor in the United States for non-proliferation reasons. He is currently battling with Congress to cut off funds from the proposed prototype fast reactor at Clinch River which he considers obsolete and unnecessary, and his personal opposition to large demonstration projects seems likely to continue.

10. The scope for negotiating collaboration with the Americans is, therefore, limited at present. Discussions with officials in the Carter Administration suggest that there could at most be agreement to embark on an expanded programme of joint research and development, coupled with an assurance that at some time in the future, to be determined later, both sides would move on to the construction

of a demonstration fast reactor and fuel plant. The possibility beyond that of joint exploitation of the technology and series ordering might also perhaps be covered but it would raise difficulties for the Americans under their anti-trust laws.

11. Looking beyond the Presidential election, even if policies change, it is not certain that collaboration with the Americans is a real option.

a. If and when the Americans decide to build commercial fast reactors they may want to do so independently. Alternatively they might prefer to collaborate with the French which would leave us very isolated.

b. Their timescale for introducing fast reactors is not necessarily the same as ours. The United States has large domestic reserves of uranium and is less vulnerable to political interruptions in supply than we are.

c. Even if they decided to collaborate with us, we might only be offered in effect a minor and inequal role in a massive United States programme.

12. Collaboration with the Americans cannot be dismissed out of hand. There might conceivably be major developments after the Presidential election. But the prospects for collaboration with the French and Germans seem more promising at present.

CO-OPERATION WITHIN EUROPE

13. The French fast reactor programme is based on a comprehensive partnership with Germany, in which Italy, Belgium and the Netherlands also have supporting roles. Super Phenix, though dominated by France, is by no means purely a French project. The Italians, for instance, play an important part in manufacturing; and even the CEGB have a small indirect stake in NERSA, the consortium of utilities which is buying the reactor.

14. Exploratory discussions have shown the French to be firmly opposed to letting the UK become partners in SERENA, the Franco/German company which controls their fast reactor technology and is responsible for licensing. But the UKAEA believe that a set of valuable agreements could be negotiated which are summarised in Annex C and would cover:

a. the cross-licensing of all design, construction and commissioning information on commercial terms;

b. co-operation on design, beginning with concentration on practical problems of current projects and aiming ultimately at a common design;

c. co-ordination of research and development programmes;

d. exchange of all fuel cycle information with France in the first instance, co-ordination of fuel cycle R & D and perhaps co-ordination of investment plans; and

e. hopefully some kind of agreement between component manufacturers though the UKAEA say that this is not easy.

15. The Germans are keen for us to collaborate. The motives of the French are not certain, but it may well be that they feel exposed in being the only country to have an expanding fast reactor programme; that they would prefer the UK to be tied into European collaborative arrangements rather than in partnership with the Americans; and that they particularly wish to have a closer relationship with us on the fast reactor fuel cycle where our technology is at least as good as theirs.

TIMING

16. Collaboration with the French and Germans should give us extra flexibility in the timing of construction of a large fast reactor. It might well be appropriate to begin construction later than 1985 to enable the information stemming from their programme to be fully assessed and assimilated. We might also want to phase our fast reactor so as to make it one of a series of European fast reactors incorporating progressive refinements in design though the benefits of such phasing would be much greater if the design of our fast reactor also represented a progressive improvement in the design of reactors being built elsewhere in Europe: in other words if the collaboration was a close one. And if in the light of the fast reactor inquiry or other developments we decided to postpone construction to the late 1980s or beyond, collaborative arrangements might still provide a way of keeping in touch with other programmes and of maintaining the fast reactor option. The French have not sought assurances from us about the timing of our fast reactor.

17. There would however be limits to this flexibility on timing. Substantial delay would bring a major loss of experienced staff in our design team with little chance of replacing them with younger people of the right calibre. Our partners might also lose confidence in us and be unconstructive in implementing their side of the deal.

COST

18. The overall cost of a fast reactor programme based on international collaboration would depend on the collaboration arrangements negotiated.

19. If our programme was still essentially independent, only absorbing foreign design and knowhow to a limited degree, and if we were building not only the reactor itself but the full fuel cycle (which would place a great demand on our nuclear fuel industry), the overall cost could still be similar to that of an independent programme: that is, around £4 billion. See Option 1. This is in essence what the proposals put forward by the UKAEA would cost. In addition, under these proposals, the French are also asking that we should pay:

a. a down-payment of £50 million for access to information on Super Phenix, Super Phenix 2 and any other reference design of reactor available to SERENA. The size of this payment is based on the extra cost of Super Phenix to which we have not so far significantly contributed.

b. royalties for the use of this information. The details would need to be negotiated but in essence we would be asked to pay at the same rate as the French Novatome Company and the German INB on any fast reactors they build. The net flow from the UK could be around £20-25 million.

20. If, however, we were aiming for a close form of collaboration, with the aim of a common European design and a series of fast reactors into which ours would be phased, we could make a significant reduction in costs one of our negotiating objectives. In particular:

a. fuel cycle. Substantial savings of the order of hundreds of millions of pounds might be achieved if satisfactory arrangements for reprocessing fast reactor fuel in France enabled us to postpone the construction of reprocessing facilities in the UK.

b. Research and development. Co-ordination of programmes should lead to a reduction of duplication and a sharing of facilities amounting to tens of millions of pounds. For instance if we had access to a number of major French facilities (e.g. roof insulation testing facilities and a rig capable of testing the fuel handling route) we would not need to build them here, and we may also need to use a 50MW steam generator testing rig which could be achieved through SERENA.

c. Capital costs. Though impossible to quantify, there should also be savings in the capital costs of our fast reactor because we would be profiting from others' experience, drawing on design improvements which they had proven and possibly saving on the manufacturing costs of some components.

21. Reduction in risk. Potentially more important than cost savings is the reduction in risk which would result from collaboration. Quantification is not possible, but the exchange of detailed engineering information combined with co-ordinated research and development should give us greater confidence that the technology has been fully explored, reduce the likelihood of major unknown factors causing delays and enable us to concentrate our resources on specific areas rather than attempt to underpin every aspect of design and construction. For instance, collaboration on fuel fabrication would allow us to concentrate on the gel process with higher assurance of success, rather than disperse resources on alternative routes as a fall-back position.

ADVANTAGES

22. Collaboration with the French and Germans would enhance our access to fast reactor technology. The closer the collaboration, the more we could seek to obtain important advantages including:

a. cost savings, particularly on the fuel cycle (paragraph 20);

b. a significant reduction in the technical and financial risks of the project (paragraph 21);

c. extra flexibility on timing (paragraph 16); and

d. co-ordination of research and development and a generally more effective use of resources.

DISADVANTAGES

23. The overall costs of a strategy based on a collaboration would still be great (see paras. 18-20) though we could look for significant savings from a close partnership.

24. The proposals which the French and Germans have so far been prepared to offer are by no means free from disadvantage:

a. we would have to pay an entrance fee of £50 million over 5 years;

b. we would also have to pay royalties to SERENA on any fast reactors we built, whereas our share in royalties on fast reactors built elsewhere would depend on our programme reaching some defined level, yet to be negotiated;

c. our manufacturing industry might well be at a disadvantage compared with their European competitors who had already established their manufacturing knowhow and would be reluctant to pass it on except at a high price;

d. we would be tied into continuing our research and development programme at roughly its present level (around £100 million or so a year);

e. we would have to agree at the outset that SERENA could pass out technology to licensees in certain specified third countries, though our agreement must be needed for all other countries not on that list.

25. More generally it would set the framework for our fast reactor policy for the rest of the century and would rule out close collaboration with the United States except in co-ordination with our European partners.

OPTION 3: A HOLDING PROGRAMME

1. We could formally defer any decision to build a commercial fast reactor until the need for fast reactors is more firmly established and maintain a holding programme in the meantime: that is, maintain a significant programme of research and development including PFR and associated fuel plants, monitor overseas programmes and possibly negotiate arrangements which give us access to foreign technology under license if and when we need it in return for our present knowhow.

OBJECTIVE

2. The aim would be to retain a substantial nucleus of fast reactor expertise in the UK but rely on overseas development work for the availability of suitable designs for commercial fast reactor plant.

OUTLINE OF THE PROGRAMME

3. This option would represent a scaling-down and major change of direction for the UK fast reactor programme whose thrust since the 1950s has been towards reliance on our own technology rather than on others. The new programme would need further detailed definition if this option were adopted, but the main outlines based on a UKAEA exercise would be as follows.

4. Dounreay. The mainstay of the programme would be the continued operation of PFR and associated plant and the maintenance of Dounreay as a major operating fast reactor site. The work carried out there would aim to provide experience with components and materials, establish the performance of fuel, help establish safety and other standards and provide data for design, operational and other purposes. The UKAEA believe that keeping Dounreay open is essential for this option both to meet these objectives and as a basis for possible limited collaboration with other countries, for instance with the Americans who regard PFR as our main asset in this field given their own lack of a prototype, or with Germany on fuel cycle work, or with the Japanese.

5. Other work. Technical support from outside Dounreay, amounting perhaps to something over 200 professional staff with supporting facilities, would also be retained. In particular:

a. Safety and plant performance. Winfrith would be the main centre for this work but it would be at substantially reduced levels.

b. Fuel performance and development. Small teams would continue at a number of UKAEA sites but there would be no major development programme, and experimental facilities at Harwell and Winfrith would probably be closed.

c. Engineering. A small team working on selected aspects would be retained at Risley. All but one of the main rigs there would however be closed down, and there would be a major effect on the site.

d. Materials and chemical engineering. Work would be reduced with teams at Risley and Harwell working on selected aspects.

e. <u>Design and project work</u> would be ended except for a small team to service PFR and meet other limited requirements.

f. <u>Fuel plants.</u> A team of some 100 professionals at Dounreay would become the nucleus of the Authority's fuel cycle expertise.

COSTS

6. The UKAEA estimate the cost of this option (excluding redundancy and redeployment costs) to be just over £1 billion to the end of the century, of which three-quarters would be spent at Dounreay. Expenditure would decline steadily through the period from £100 million today to around £17 million in 2000, with minor savings possible over the next three financial years. Details are in Table 2. The figures assume that the rundown is planned in detail in 1980 and commences at the end of 1980/81.

7. These estimates are not necessarily reliable in the sense that if later in the century the need for fast reactors became pressing, the decision was reversed and continuation of a prototype and its fuel cycle began under foreign licence, the costs would mount sharply and the overall cost of the strategy might be much closer to the cost of a strategy based on option 2.

ADVANTAGES

8. If this strategy was successful, it would cost a great deal less than a strategy based on the construction of a large fast reactor: roughly £1 billion compared with the £4 billion over 20 years estimated for a fully independent programme. Even allowing for the construction of a thermal nuclear power station of equivalent capacity, the cost differential could still be close to £2 billion.

9. We would be leaving the teething problems of large fast reactors to be solved by other countries and allowing our nuclear industry to concentrate on the priority task of establishing our thermal reactor programme.

10. At the same time we would hope to keep alive some ability to introduce fast reactors developed elsewhere when we need them, and to have some freedom of choice about how we did this. We might, for instance, want to revive the question of collaboration with the United States if policies changed there; or we might decide later to seek a licence from SERENA, adapting it to meet our own safety and other requirements as necessary; or we might co-operate with the Germans on fuel cycle work.

DISADVANTAGES

11. We would however be gambling on world uranium supplies not coming under pressure until well into the next century and on there being an acceptable design of fast reactor available to us for licensing from SERENA or the United States when we needed it. Estimates of the royalties which licensors might charge in these circumstances have ranged from 5% to 20% of the capital costs of each station, assuming indeed that they would be prepared to sell licences at all.

12. We would be dispersing our industrial design teams and giving up our present ability, acquired at some cost over 25 years, to introduce fast reactors to our own standards and on the basis of our own experience. The leadtime for introducing fast reactors when we needed them might well be long.

13. How far it would be possible to attract and retain professional staff of the right calibre just to run a holding programme is a matter for doubt.

14. The lack of involvement of British industry in the development and production of components in the period before the licence was taken would leave them at a disadvantage in competing against overseas manufacturers as suppliers for the first UK fast reactors.

15. If the strategy was unsuccessful and we had to reverse it later in the century, building a fast reactor and its fuel cycle earlier than we had hoped under foreign licence, the costs would mount up sharply again.

OPTION 4: WITHDRAW

1. We could decide to rely entirely on being able to buy an overseas licence for fast reactor technology if and when we needed it, and run down our present programme including PFR and Dounreay.

OBJECTIVE

2. The aim would be to avoid the heavy costs and risks involved in a CDFR to cut back and save as much as possible of current fast reactor expenditure and to free the highly skilled resources employed in the UKAEA's programme for other productive uses in the economy.

3. The major difference between this and the previous option would be the closure of PFR and the running down of the Dounreay site to a care and maintenance basis. Fast reactor work in other establishments would also cease and the UKAEA would become a radically different and smaller organisation. We would need to take steps in due course to try to obtain an overseas license for for use as and when we needed it.

COST

4. The costs of this option to the end of the century would be comparatively low, around £320 million (excluding redundancies) plus a possible £50 million or more for the final decommissioning of reactors and plant at Dounreay. The bulk of the expenditure would be in the next few few years as the rundown of Dounreay took place. Even so, minor savings might be possible over the next three financial years.

ADVANTAGES

5. We would avoid the heavy costs and risks of a CDFR, make a substantial cut in public expenditure and free the nuclear industry to concentrate on the thermal reactor programme.

DISADVANTAGES

6. We would however be writing off the experience and understanding of fast reactors which has so far been built up at some cost in this country, a decision which could prove very costly if world uranium supplies come under pressure.

7. We would be totally dependent on other countries' progress with fast reactors and on their ability and willingness to make the technology available to us on acceptable terms.

8. We would have no infrastructure to support the introduction of fast reactors. Our ability to assess designs in the light of our own safety and operating requirements would be very limited; and the introduction of reactors could be delayed for years by our lack of expertise.

9. Our nuclear engineering and manufacturing industries would find it difficult or impossible to compete with overseas suppliers already involved in the production of fast reactor components.

CONFIDENTIAL

COST ESTIMATES FOR UK "BUILD CDFR" FAST REACTOR STRATEGY (£M AT 31.3.80)

CONFIDENTIAL

	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/2000	Total
Reactor Programme																					
CDFR: Capital					24	48	166	273	309	226	120	24									1190
IDC						3	10	23	43	63	73	75									290
Operations											1	3	6	16	20	23	20	19	16	16	140
R&D (AEA)	48	55	60	61	59	59	50	44	36	29	25	22	19	17	15	11	9	5	3	3	630
R&D (NPC/Industry)	11	14	20	28	31	20	15	9	5	4	–	–	6	5	4	3					175
PFR: Operations (net)	30	25	24	19	14	13	11	10	10	10	10	9	9	9	8	8	6				225
Fuel Plants (Capital and Design)				3	6	10	18	20	14	14											75
Pu hire/ reprocess	13	11	11	11	11	11	11	11	11	11	11	11	11	11	11	10	8				185
Fuel Plants Programme																					
Fabrication Plant:																					
Capital (inc. IDC)					3	5	13	13	12	12	14	3									75
Operations											1	24	24	19	19	19	19	19	23	23	190
Reprocessing Plant:																					
Capital								38	56	106	106	106	63	25							500
IDC								1	5	10	18	25	33	33							125
Operations														10	10	9	9	9	9	9	65
R&D (Fab. and Rep.)	1	4	4	4	14	14	11	8	5	5	4	4	4	4	4	3	3	3	3	3	105
TOTALS	103	109	119	126	162	183	305	450	506	480	383	306	175	149	91	86	74	55	54	54	3970
Credit PWR Costs:																					
Capital										14	49	140	196	189	91	21					700
IDC											1	9	20	33	41	46					150
Initial Fuel															45	45					90
Operations															3	6	18	16	16	16	75
Replacement Fuel																	40	40	40	40	160
Launching Cost												6	6	6	7						25
TOTALS										14	50	155	222	228	187	118	58	56	56	56	1200

NOTES: 1. There is no customer post-contract allowance included in the reactor (CDFR, PWR) costs presented, or in the fuel plant costs.

2. CDFR Initial Fuel has been omitted as a separate item as the cost is covered within the costs of the Fuel Plants Programme.

3. No post-contract contingency has been included on the reactor items in this Table.

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TABLE 2

COST ESTIMATES FOR UK "HOLD" FAST REACTOR STRATEGY (£M AT 31.3.80)

	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/2000	Total
<u>UKAEA</u>:																					
PFR: Operations (net)	30	25	24	19	14	13	11	10	10	10	10	9	9	9	8	8	6				225
Fuel Plants (capital and design)				3	6	10	18	20	14	4											75
Pu hire/reprocess	13	11	11	11	11	11	11	11	11	11	11	11	11	11	11	10	8				185
Other Dounreay operations (inc. capital)	15	14	14	14	13	11	11	11	13	14	15	15	15	15	15	15	14	13	10	8	265
Other Establishments	33	21	14	12	12	11	11	11	11	11	11	11	11	11	11	11	11	10	8	8	250
R&D (NPC/Industry)	9	1																			10
R&D (BNFL)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
TOTALS	101	73	64	60	57	57	63	64	60	51	48	47	47	47	46	45	40	24	19	17	1030

TABLE 3

COST ESTIMATES FOR UK "DROP" FAST REACTOR STRATEGY (£M AT 31.3.80)

	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/2000	Total
<u>UKAEA</u>:																					
Dounreay	58	41	36	29	20	13	9	5	3	3	3	3	3	3	3	3	3	3	3		247
Other Establishments	33	20	9	3																	65
R&D (NPC/Industry)	9	1																			10
TOTALS	100	62	45	32	20	13	9	5	3	3	3	3	3	3	3	3	3	3	3		322