perhaps the first of many. Money is to be spent, and there are contracts to be had. That means large and powerful interests are involved, not just on both sides of various sectors of manufacturing industry, but within state administrations and institutions and within the EEC's own administrative structures.

With so much at stake, the decision on the site had to become the prime focus of interest. To win JET was (and is) to win fusion in Europe. There are some, notably the Italians, who have claimed that JET, being just one part of an even larger overall programme, would not by its location determine where the European centre of excellence would lie. The argument is that the other projects to come would be sited elsewhere. But no one seems to believe it. Whoever wins JET, most are saying, acquires the huge investment that goes with it, the location for future reactors and the investment that goes with them too; whatever the spreading of the contracts, and no matter what clauses are inserted as safeguards into the agreement, the host country is said to have the advantage. That country's cap acquires the fusion feather—and the reputation, the prestige and the national pride. It seems rather a lot to hang on a unanimous decision of a group of Research Ministers.

The Commission, in the form of Signor Palumbo, finds all this a trifle exaggerated. He claims that the press has "transformed a technical and limited problem into one of prestige", and points out that there is another aspect of the problem beyond the interest of a country in having JET. This is the interest in having JET at the best possible site. Suppose, he says, a super-intelligent, objective man could identify both the best and the worst sites among those competing for JET. The difference between the value of the best site and the value of the worst site, he argues, is hugely outweighed by the damage done by a one-year delay to the JET project and to the common fusion programme. Indeed, all sites could host JET. The choice of the site, while blocking everything, is thus irrelevant, he claims, and he goes on the repeat the growing view—that if the Commission's choice is not approved, the Council of Ministers must give up its jealously guarded unanimity rule to come to a definite choice.

He certainly seems to be right about the urgency. Existing programmes for medium scale devices at Jülich, Cadarache, Garching and Culham all depend technically and financially on a decision on the site for JET. Delay is discouraging the JET staff even further, making it difficult to maintain the team and impossible to expand it. It has been possible to farm out some small study contracts relating to the project, but money available for this is almost totally spent, and a Council decision is required for more. Plans for buildings cannot be finalised, of course, buildings cannot be built, and orders cannot be placed for equipment that might be unsuitable or superfluous if another site is chosen. As the Commission has itself put it, any decision concerning further work without the site being known would be unrealistic, perhaps dangerous and almost certainly expensive.

Just how expensive is perhaps not appreciated. The delay, apart from jeopardising the project itself and the whole fusion programme, may now be jeopardising the spirit of cooperation that exists in Europe. It may also be damaging the credibility of the Community's decision-making procedures among other international organisations and in other non-EEC countries. Most importantly, it may soon start affecting Europe's own public, whose tacit support for the expenditure of so much money is less likely if the persistent delays (and the corresponding progress of the Americans and Russians) make the project seem pointless.

Optimists point out that a decision in October would mean that a delay of only a year had been incurred. No decision in October might mean leaving the decision as late as the next Heads of Government meeting in The Hague in December. But the viability of the whole project may have been brought into question by that time: as Herr Schuster, Director General at DG XII in Brussels, puts it, if there is no decision by then, the project is dead in an EEC framework. Yet it is Schuster who freely acknowledges that the German elections later this year might intervene, Italian-style.

An alternative has already been mooted: that JET becomes a British–French–German operation. But a British minister has already said Britain is committed to European collaboration. And the Commission heaps derision on the idea. Alternative combinations, it is said, are "futurology": the three countries can't agree among themselves, and JET is anyway "owned 100%" by the Commission. But political facts could conceivably change things. The Community is being brought into disrepute. Fusion itself is being brought into disrepute. Unless something is done, a Community fusion project might therefore be a forlorn hope. □

Tracking nuclear decisions (2)

FBR: will it ever be stopped?

Allan Piper looks at the arguments concerning the fast breeder reactor

THE UK Energy Secretary, Anthony Wedgwood Benn, decides this autumn whether Britain will build a commercial scale fast breeder reactor. It is a measure of the task he faces that, from one viewpoint, the FBR is an elegant and timely solution to immediately foreseeable energy problems, while from another it looks like potentially the most disastrous technological development imaginable. The dichotomy is simply explained: the reactor's most attractive advantage—an ability to create its own fuel—is precisely its major disadvantage. For the fuel so created is plutonium, the stuff of nuclear weaponry.

Mr Benn is fully aware of the enormity of his decision's implications, whatever he chooses. Not much is known of how he will reach it, beyond the fact that a certain amount of public debate is involved. Some people believe the decision is being taken too quickly and ought to be delayed, saying the FBR is not yet needed; others contend that an early decision is vital for the industry and the country. The arguments are complicated, but what Mr Benn has to decide is, first, whether fast reactor technology is an essential element of the future energy scene; second, whether it can be developed to an acceptable level of safety; and, finally, whether it is socially desirable. He must make his decision against a backdrop of clear signs that the FBR will be developed elsewhere if not in Britain, and delay could spoil the chances of an early foothold in a potentially lucrative worldwide market.

The case for the FBR rests squarely on its fuel breeding capacity (see box, page 344). Unlike existing commercial thermal reactors, which use less than 1% of the energy available in uranium, the FBR extracts more than 60%. At the same time it contributes towards future energy supplies by "breeding" plutonium. These simple advantages mark it out as the potential saviour of an energy hungry world.

Consideration of Britain's nuclear fuel prospect highlights the possible benefits of the FBR. Since the middle 1950s the UK thermal reactor programme has produced 20,000 tons of depleted uranium. Ordinarily of little value, this stackpile, together with the 13 tons or so of plutonium that have also accumulated, could be used in fast breeders to provide as much energy as the nation's total known reserves of coal. For a country with a sizeable (5 GW) and expanding nuclear programme, this represents an indigenous energy source that could become ever more crucial as the domestic requirements of the uranium exporting nations themselves increase. British imports from Canada could be squeezed, as could possible future supplies from Australia. A large political question mark hangs over Namibian uranium, Britain's only other source of reactor fuel.

Worldwide nuclear expansion will also introduce economic pressures. Present assessments of world uranium reserves are as elastic as the market prices assumed in calculations, but at the existing price of around $15 a pound an estimated 3.4 million tons of high grade ore are available, though only half of that is so far proven. Whether this can last beyond 1990, even with today's worldwide nuclear capacity, is already a matter of debate.

There is less doubt, however, that by the turn of the century the continued use of thermal reactors alone could force the exploitation of lower grade ores. The consequent increase in prices, which might rise as high as $100–$200 a pound if forecasts from the US Energy Research and Development Administration prove correct, is likely to be matched only by the increased amount of environmental despoliation accompanying the extraction of ores with energy contents similar to that of coal. (Currently used ores provide around 25,000 times as much energy as coal in thermal reactors, or up to about 1.5 million times as much in fast breeders.)

What bearing this has on the case for a British FBR programme is rather a matter of viewpoint. On the one hand, energy demand forecasts from within the nuclear industry and the Department of Energy (DEN) identify the FBR as an indispensable cornerstone of the British energy scene until fusion power arrives. On the other, it is easy to query the accuracy of forecasts. The degree of uncertainty involved was underlined during the recent national energy conference when British Gas leaders refuted predictions of a UK energy gap before the end of the century.

Independent research units similarly believe that electrical energy demands may already be near to peaking, while pressure groups claim that demand can be regulated by conservation measures, ensuring that sufficient nuclear capacity is achieved economically using more efficient thermal reactors systems such as CANDU (see box). There are also calls for more research and development (R&D) effort on high temperature reactors, which open up the possibilities of the thorium cycle. But the UK Atomic Energy Authority (UKAEA) is less enthusiastic, wary of the huge initial uranium investments needed to launch such a programme.

Photo: UKAEA

Prototype Fast Reactor with the Dounreay Fast Reactor in the background

UKAEA forecasts predict that by the turn of the century almost 75% of the national energy demand must be met by nuclear power. Of the 198 GW needed to do this job, almost 33 GW, nearly seven times the current total installed nuclear capacity, will come from fast breeders. Whether this target is treated entirely seriously by the DEN remains doubtful, particularly as the Central Electricity Generating Board (CEGB) could by then handle a maximum of only 20 GW from FBRs. Moreover, Walter Marshall, Chief Scientist at the DEN, has several times publicly voiced the conviction that the number of commercial fast breeders operating by the year 2000 is unlikely to exceed two or three.

Nonetheless, this only reinforces the UKAEA's case for early clearance for their planned 1,300 MW demonstrated FBR, CFR–1. It has built up a good head of steam for the off. Its R&D effort on FBR technology extends back over 25 years, with operational experience dating from the start-up of the 14 MW experimental FBR at Dounreay in Scotland (DFR) in 1959. The programme advanced a further major step two years ago with the introduction at low power of a 250 MW prototype (PFR), also at Dounreay.

Estimates of the total cost involved in coming thus far vary between £200 and £400 millions, but the UKAEA's present level of financial commitment speaks for itself. Though cuts of up to £4 millions are expected as part of current UK expenditure savings, R&D spending on FBR technology over the past three years has stood at around an annual £40 millions, almost a third of the total nuclear R&D cake, and by far the largest single slice. Moreover, about half of the overall nuclear R&D workforce is involved with the FBR.

The UKAEA therefore understandably feels that the next logical step is the design and construction of CFR–1, expected to take about 10 years. Confidence generated by almost two decades of reasonable progress with DFR, which has pumped more than 500 kWh into the national grid, extends beyond the reactor itself, into every area of the related fuel cycle.

At least one group does not share the UKAEA's confidence. Friends of the Earth (FOE) have vocally attacked the international record of fast reactor development with single minded conviction. During a recent House of

Commons Select Committee meeting FOE listed a series of developmental setbacks that provokes sober reflection. The Enrico-Fermi FBR in Detroit, Michigan, for example, was constantly beset by potentially dangerous disruptions during its sporadic, nine-year operational life, while more recently the Soviet BN–350 FBR on the Caspian coast has suffered several serious leaks in the steam generating plant. Welding has, indeed, proved a persistent problem, and has delayed the full-power operation of the Dounreay PFR. The molten sodium used in the cooling circuits is highly corrosive. Void formation—the occurrence of gas bubbles in the coolant—is another major problem common to all FBRs and has still to be overcome.

Remaining hitches in reactor technology can, it is argued, be straightened out during the 20-year run-up to a commercial FBR network. But doubts linger over the associated fuel cycle. They arise not only at the technological level, where experience already gained by British Nuclear Fuels Ltd has been encouraging, if somewhat controversial, but also at environmental and political levels.

In a submission last year to the Royal Commission on Environmental Pollution (RCEP), which is due to publish a report on radiological hazards before Mr Benn's autumn decision, the UKAEA covered the environmental issues. Its arguments that the hazards of long-lived, highly active wastes can be satisfactorily controlled are likely to tip the scales in favour of the FBR. Mr Benn has indicated that the RCEP report will influence his decision, and it is now clear that the Commission itself, for some time reportedly divided over nuclear issues, will back CFR–1. In a recent reference to commercial FBR development Sir Brian Flowers, Chairman of the RCEP, said that while the implications and alternatives had not been explored with the level of resources and dedication devoted to the nuclear programme itself, he would not oppose the building of CFR–1 alone.

But the social and political implications of FBR reprocessing most worry those who believe that one step forward to CFR–1 will carry too much momentum for subsequent withdrawal. Though FBRs produce plutonium at a slower net rate than thermal reactors their proliferation would introduce the need for widespread plutonium transport. On UKAEA reckoning there could be 250 tons at various stages of the fuel cycle in Britain by the year 2000.

FBR opponents fear that the security measures required would be not far short of Draconian. A Bill to introduce the arming of nuclear security police has already been passed by the UK Parliament, and a US Government official this month called for an armed international security force. Additional doubts have been expressed about the sort of political arrangements needed to ensure worldwide adherence to safeguards such as those already implemented on a more limited scale by the International Atomic Energy Agency.

In France, the political and technological fears have led to civil disturbances involving qualified and well-informed opponents of the 1,200 MW Superphénix project now beginning on on the Rhône. But in Britain there is little public awareness of the issues. Sir Brian Flowers recently charged that the UK Government apparently preferred to keep things in the dark. Similar concern has also led the Liberal Peer, Lord Avebury, to call for a Green Paper once the RCEP report is available, and to hint that a national referendum would not be inappropriate. Mr Benn has said only that a questionnaire will be produced for limited, and so far unspecified, circulation.

Though it is clear that the case for

How the FBR is different

NUCLEAR power installations harness the heat energy released during controlled nuclear fission, and convert it into usable electricity. Fast breeder reactors (FBRs) differ from existing commercial reactors (known as "thermal" reactors) because, along with energy, they produce more fissile material than they consume—a self-sustaining bonus which could considerably stretch world uranium resources.

Like fast breeders, thermal reactors produce some plutonium but only in minute amounts. This is because more than 97% of the uranium used in thermal reactors fuel is non-fissile uranium-238, which is partially converted into plutonium while fission of the small fraction of uranium-235 proceeds. But plutonium is itself fissile, and most of it rapidly breaks down again, adding to the overall energy output of the system. (The Canadian CANDU reactor is designed to take full benefit of this phenomenon, optimising fuel efficiency.) Thus only about 1% of spent fuel from thermal reactors remains as plutonium.

On the other hand, the FBR can breed plutonium, using fast neutrons rather than the slow neutrons used in thermal reactors. Although fast neutrons are less efficient in inducing fission, the chain reaction they set up produces the greater number of additional neutrons needed to convert uranium-238. Consequently, the moderators used to decelerate fast neutrons in thermal reactors are absent from fast breeders.

The problem of decreased fission efficiency is overcome by pushing the neutron density in FBR fuel elements above the level achieved in thermal reactors. This means that the core assembly must be extremely compact, while the concentration of fissile material must be boosted way above the maximum enrichment factor of 3% needed in thermal fuel.

The 14 MW experimental FBR at Dounreay (DFR), for instance, uses 75% enriched metallic uranium in a core of little more than 100 litres. At Dounreay, as in all FBRs, the uranium-238 needed for breeding is located in a "blanket" around the core, where the neutron density is no longer sufficient to break down the fissile plutonium formed.

In assessing the doubling time of an FBR—the period required for the reactor to reproduce the amount of fissile material originally in the reactor core—the entire fuel cycle is considered. At any one instant, for example, fissile material may be within the reactor itself, undergoing cooling, reprocessing or re-fabrication, or in transport.

It is thus possible to control the doubling time by retiming any of the operations involved in the cycle. Current UKAEA plans envisage a doubling time of about 28 years for Britain's first commercial FBRs early next century, a figure that neatly matches the expected expansion rate of the reactors themselves.

With the high neutron density in an FBR core, heat is generated more efficiently than in thermal reactors. Thus, while most thermal reactors operate at temperatures well below 300 °C, the 250 MW prototype FBR at Dounreay (PFR) has a design outlet temperature of almost 600 °C. Fast breeder fuel elements must be designed to withstand the extra heat.

It soon became apparent that the metallic uranium core used in the DFR would melt at operating temperatures above 350 °C. As a result, the PFR is fuelled by sintered pellets of uranium oxide and plutonium oxide. Uranium-235 is not an essential component, however, and fast breeders of the future could be fuelled with fissile plutonium-239 alone, though uranium-238 breeding material would, of course, have to be present. It is in by-passing the need for the scarce uranium-235 isotope that the FBR can stretch available uranium resources.

The fast breeders so far developed in Britain, France, Germany, Japan, the USA and the USSR are all designed to use liquid metal coolant circuits to carry the heat away from the core. They are therefore known as liquid metal fast breeder reactors. By using sodium, which is normally molten between 98 °C and 880 °C, the unnecessary hazards associated with pressurised operation procedures can be avoided.

To minimise the risk of radioactive contamination, sodium circulated around the core in the primary reactor chamber passes its collected heat onto a secondary, external sodium circuit shielded from radiation. This circuit in turn carries heat to the steam generators.

FBR development has not run altogether smoothly. After 17 years operational experience with the DFR and the PFR, the UK nuclear industry is still struggling with problems in the steam generating plant of the PFR. The CEGB, however, which is prepared to have 20 GW of FBR capacity plugged into the national grid by the year 2000, has also declared a watchful interest in the development of helium-cooled fast breeders, which could provide an even better alternative to the liquid metal FBRs.

the FBR is far from open and shut, Mr Benn's view of international developments may persuade him to nod CFR-1 through. France, Germany, and the USA are all aiming for commercial FBR capacity by the 1990s, with Japan and Russia not far behind. UKAEA collaboration agreements already exist in one form or another with all of these countries, while the CEGB, currently chasing a minor share of the Superphénix project, also holds an interest in the German SNR-30 FBR prototype.

UKAEA feeling is that delays with CFR-1 will not help strengthen collaboration, perhaps damaging Britain's relative position in a commercial development race that will be run anyway. One man who disagrees is John Surrey, who last month resigned as nuclear adviser to the Select Committee on Science and Technology. He has argued publicly that Britain can learn much from the sidelines, and that restraint at this stage will allow the channelling of larger funds into other areas of energy R&D, including conservation. The UKAEA must hope that Mr Benn is unimpressed by that reasoning: it has already placed a contract with the Nuclear Power Company for design and engineering work "related" to CFR-1. On the question of a possible site, there has been official silence. □

Tracking nuclear decisions (3)

Exports: time for a stand?

Colin Norman in Washington examines the NRC's problems concerning the export of uranium to India

EARLY next month, the Nuclear Regulatory Commission (NRC) will decide whether to allow 12,261 kg of slightly enriched uranium to be exported to India. Its decision, the toughest it has yet faced, will have major foreign policy implications, for it will represent a crucial milestone in the United States' efforts to prevent the proliferation of nuclear weapons. In fact, it is the kind of foreign policy decision that is usually made by the President.

NRC is thrust into the middle of the issue because it alone has the authority to grant or deny an application for a licence to export nuclear material from the United States. Its decisions can only be overturned by an Act of Congress. In this instance, it has under consideration an application to export fuel for the giant Tarapur Atomic Reactor Station near Bombay, an American-built reactor which has been operating since the early 1960s with fuel supplied by the United States.

Understandably, NRC is treating the matter with considerable caution. Last week, it held a public hearing to receive testimony on the licence application—the first public hearing ever called to discuss a nuclear export licence—and it was given a wealth of conflicting advice. On the one hand, the State Department and the Commission's own staff recommended that the application be approved, while on the other, a powerful coalition of arms control experts, Congressmen, environmentalists and nuclear critics argued that the licence should be denied.

Underlying the debate, of course, is the fact that on May 18, 1974, Indian scientists exploded a nuclear device constructed from plutonium produced in a Canadian-supplied reactor. It was the first time that any nation had used imported technology to join the nuclear club, and as a result Canada earlier this year decided to bar any further nuclear assistance to India. Opponents of the request to ship enriched uranium for the Tarapur reactor are urging that the United States should follow Canada's example.

Representative Clarence D. Long of Maryland for example, told NRC that "our response to India is the first test of whether the United States has a real policy of stemming the spread of nuclear weapons". Similar sentiments were also expressed by Dr Herbert Scoville, former deputy Director of the Central Intelligence Agency, and Adrian Fisher, former chief negotiator for the Nuclear Non-proliferation Treaty (NPT). Fisher argued, for example, that "the continued supply by the US of nuclear fuel for the Indian atomic program can only be looked on by other nations as tacit approval by the United States of the Indian nuclear explosive program".

The United States has been supplying enriched uranium for the Tarapur reactor for more than a decade under a unique agreement. In short, the agreement specifies that the reactor can only be operated with fuel supplied by the United States, and that such fuel cannot be used in any other facility in India. The United States also has an option to buy back spent fuel discharged from the reactor—nearly 200,000 tons have so far been accumulated—and no reprocessing of that fuel can take place in India without US permission. Moreover, operation of the Tarapur reactor is subject to monitoring by the International Atomic Energy Agency (IAEA).

But India has an extensive nuclear programme in addition to the Tarapur reactor which is not covered by the agreement and which is not subject to international safeguards. The explosive device detonated in 1974, for example, was made from plutonium produced in a Canadian-supplied research reactor and separated in a small reprocessing plant built by the Indians themselves. And a new factor has recently been introduced because India has recently completed construction of a large reprocessing facility adjacent to the Tarapur reactor. According to State Department spokesmen at last week's NRC hearing, the facility is now undergoing tests and it will soon have the capacity to reprocess much of the spent fuel from India's entire nuclear programme. The construction of the plant has given India at least the capacity of building large numbers of explosive devices.

Opponents of the proposal to ship more fuel for Tarapur, led by the Natural Resources Defense Council, the Union of Concerned Scientists and the Sierra Club, argued at last week's hearings that, at the very least, NRC should deny the application until India has agreed to several stringent conditions. First, the Indian government should pledge not to construct further explosive devices. Second, the United States should exercise its option to buy back spent fuel already produced by the Tarapur reactor. Third, India should agree to place all its nuclear facilities under international safeguards. And fourth, India should agree not to reprocess any spent fuel, at least for the time being.

Clearly, the Indian government would not readily accept such conditions. But the opponents of the licence application point out that India would be hard pressed to find an alternative fuel supplier. The only other exporter of enriched uranium is the Soviet Union, and potential European exporters are at least ten years away from having significant export capacity. Thus, they argue that "if India wishes to avoid a shut-down of the Tarapur reactors, it may well have to deal with the United States, and the Commission has leverage to obtain non-proliferation ends".

But those views are not shared by the State Department. In a long statement delivered to the NRC last week, for example, Assistant Secretary of State Myron Kratzer argued that "the credibility of the United States as a reliable supplier of nuclear materials, equipment, and services is an essential ele-