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REVIEW OF THE STATUS OF AND ASSESSMENT OF THE PROSPECTS FOR THE ESTABLISHMENT OF PLUTONIUM RECYCLE IN THERMAL REACTORS IN THE FORATOM COUNTRIES

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FOREWORD

After the Foratom Congress in Madrid, May 1976, a Foratom Working Group was formed to continue the discussion on Pu recycle in thermal reactors which had been raised at the Congress. This paper is presented on behalf of this Group. Those who have contributed include:

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1. INTRODUCTION

During the 1960's a number of development programmes were initiated in the US and in Europe which were aimed at establishing the feasibility of plutonium recycle in LWR's by the fabrication and irradiation of demonstration quantities of mixed oxide fuel but although these programmes were essentially successful they have not lead to continuing commercial plutonium recycle anywhere in the world. Dollard (1) summarised the situation in the USA at the end of 1975 when, in the light of the interminable delays in the establishment of reprocessing capacity and the anticipated timescale of the hearings on the NRC Generic Environmental Statement for Mixed Oxide Fuel (GESMO) with its Safeguards Supplement, he did not envisage the establishment of plutonium recycle in the US before 1983/84. Since then, the prospects in the US have been made even more uncertain by the statement of the President in October 1976 in which he announced that there was to be an evaluation of reprocessing and recycle and that these steps in the fuel cycle should be pursued only if found consistent with non-proliferation objectives (2).

In Europe, Belgium, Italy and Germany have actively pursued the plutonium recycle option but the establishment of recycle on a substantial scale has been inhibited by lack of reprocessing capacity and hence by a shortage of plutonium. However, if the planned reprocessing capacity becomes available during the 1980's there should, on any reasonable assumption of fast reactor installation, be a surplus of plutonium for at least a limited period. This paper, therefore, reviews the status of the technology and the policies of the various FORATOM countries and attempts to assess the prospects for the establishment of plutonium recycle in Europe.

The assumption is made that the nuclear power programmes of the various countries will proceed and that reprocessing capacity will be installed at least in line with the lower projections of the recent OECD survey (3) and summarised in the Appendix. It is recognised that there are political uncertainties which could invalidate this assumption but it is not considered appropriate to speculate on the effect of any increase in the antipathy of the general public and Governments towards nuclear power and in particular towards the use of plutonium as a fuel or on the implications of international concern in regard to security, safeguards and non-proliferation.

2. MIXED OXIDE FUEL FABRICATION EXPERIENCE

As plutonium is several orders of magnitude more radiotoxic than uranium, the incorporation of plutonium into nuclear reactor fuels requires special fabrication techniques which are not necessary for the fabrication of uranium fuels. Up to the present time, plutonium processes have been carried out in sealed glove boxes operating at slightly negative pressure in order to prevent any outward leakage and although this makes plutonium operations much more complicated, and therefore expensive, in relation to similar operations on uranium, the engineering of these facilities has been reasonably well established. However, there are two further unique constraints as compared with UO_2 fuel

(1) The plant operators and maintenance workers have to be protected from radiation doseage.

(2) The high radiotoxicity of plutonium means that the amount of plutonium contaminated waste, eg gloves, swabs and expendable or redundant equipment has to be kept to a minimum in order to minimise treatment and disposal requirements.

These demand maximum primary containment to minimise the desposition of dust on the interior surfaces of the sealed facility, adequate shielding of the operator from dispersed and bulk sources and equipment of the highest reliability.

In view of the above, it is not feasible to fabricate mixed oxide fuel in a UO_2 fuel plant and plutonium fuel fabrication in Europe has progressed from laboratory scale development in the 1950's through the pilot plant phase in the 1960's to the stage where there are prototype commercial plants in operation in Belgium, France, Germany and the United Kingdom with capacities as follows:

TABLE 1

PLANT	Annual Capacity (te HM)	
	LWR	FBR
Belgonucleaire, Dessel	38*	7*
CEA, Caderache, France	15	5
Alkem, Hannau, Germany	40*	10*
BNFL, Windscale	-	10
TOTAL	93	32

*NOTE these capacities are alternative not additive

In Europe, as well as the USA, during the 1960's, there was some promotion of crushed UO_2 vibratory compacted (Vipac) fuel and this carried over into mixed oxide (UO_2/PuO_2) demonstration programmes, but the claimed advantages were not validated and for some years now all the major manufacturers have concentrated on the pressed pellet concept for both UO_2 and mixed oxide fuel.

The mixed oxide pellet fuel made in Europe up to the present time amounts to about 20 tonnes of relatively high enrichment (up to 30% Pu) for the Phenix, PFR and SNR fast reactor projects and about 50 tonnes of low enrichment fuel (up to 5% Pu) for irradiation endorsement in various thermal reactors (Table 2). Apart from that made in the UK for PFR, where the required blend of PuO_2/UO_2 was co-precipitated as powder, all this fuel has been made by a conventional UO_2 pellet fabrication route with the addition of a UO_2/PuO_2 blending operation at the powder stage. In the finished pellet, this results in a dispersion of PuO_2 particles in the UO_2 matrix and it is necessary to set standards of micro-homogeneity in order to limit the heat flux peaking arising from the segregation of plutonium into plutonium rich areas. A further requirement on micro-homogeneity which arises from re-processing considerations is discussed in Section 5 and these

requirements do impose restrictions on the characteristics of the starting materials and on the fabrication routes, which are not met with on UO_2 fuel.

There is thus substantial experience in Europe of the fabrication of mixed oxide pellet fuel for LWR's, on the prototype commercial plant scale and it can be said that the experience on operator doseage has been generally satisfactory. However, as the radiation emitted from plutonium comes predominently from Pu238, Pu240 and Pu242, it increases with the irradiation level of the fuel from which it is extracted and with continuing recycle as this increases the cumulative irradiation. In this context it must be acknowledged that most of the plutonium fuel manufactured to date has been from first cycle low irradiation plutonium and that although for multiple recycle some alleviation will be obtained by dilution with new plutonium, future production scale plants will have to be engineered to accommodate an increase in radiation level from the fuel being fabricated by something like a factor of 3 as compared with present experience. This, coupled with a trend towards reduction in regulatory limits on radiation doseage, will demand higher standards of primary containment, operator shielding and equipment reliability together with remote operation wherever practicable. Nevertheless, with the experience gained to date, there is confidence that it should be possible to build such plants which will meet these and other environmental requirements including the minimising of contaminated waste arisings (4).

In view of the radiation problem from dust mentioned above, it is arguable that there would be some advantage in having a fuel fabrication route which eliminates a powder stage and consequently consideration has been given in most countries to a so called "wet" route. At Petten the RCN have developed a fuel concept known as "Vibrasol" (5) which is based on the vibro-compaction of oxide spheres produced by a gel precipitation process, a similar line of development is being followed on the laboratory scale by GFK at Karlsruhe in Germany (6) and also in the UK but in the context of fuel for the commercial fast reactor (7). However, because of the entrenched position of the UO_2 pellet for LWR fuel, the main line of development on mixed oxide fuel fabrication has continued to be on the pellet concept and although the technical results of the Dutch programme were encouraging, it has recently been abandoned due to the lack of commercial prospects. Nevertheless, in view of the extended timescale now envisaged for the establishment of plutonium recycle, if the gel vipak concept is seen to have advantages in the "out of reactor" parts of the fuel cycle it is possible that in the future it could be promoted as an alternative to pellet fuel.

Whatever the fuel concept, an important matter in relation to security is the starting material and unless all plutonium fuel fabrication plants are to be located on the reprocessing sites it will be desirable to standardise on the base material to be supplied by the reprocessors. In this context, the advantages of eliminating the possibility of access to PuO_2 or PuN are clear, so that for the pellet route the obvious choice of base material is mixed oxide but the precise composition and form will be a compromise between considerations of reprocessing, storage, transport and fabrication.

3. REACTOR EXPERIENCE

Demonstration irradiations of mixed oxide fuel in LWR's have been carried out in Europe since the early sixties, both as part of a EURATOM programme and by individual countries. Table 2 summarises the demonstration programmes in the FORATOM countries and shows irradiation in a number of reactors of several thousand fuel rods manufactured in Britain, Belgium, France and Germany.

The experience acquired to date has been very encouraging from the fuel performance and reactor operation points of view. In particular the success of the Belgian, German and Italian programmes has led to the acceptance of significant quantities of mixed oxide rods in the reload fuel for BR3 (30% since 1972), Kahl (25% since 1969) and Garigliano (½ core since 1975).

4. STATUS OF PLUTONIUM RECYCLE IN THE FORATOM COUNTRIES

Until very recently the general assumption in Europe has been that all irradiated fuel would be reprocessed and therefore that the plutonium produced would become available for use and whilst there was no disagreement that it could be utilised more efficiently in the fast breeder reactor than in recycle in thermal reactors, there have been differences in policy between the different countries related to their respective positions on fast breeder development and on the provision of their own fuel plants. The present situations in the various countries in respect to plutonium recycle are summarised briefly below.

Austria

The attraction of plutonium recycle to electrical utilities is recognised but the reprocessing of mixed oxide fuel is thought to be a considerable problem.

Belgium

Mixed oxide fuel fabrication is well established at Belgonucleaire where a 38 tonne/annum commercial prototype plant has been in operation since 1973 and tonne quantities of fuel have been provided for irradiation demonstration programmes in various European reactors. Latterly, however, further commercial exploitation has been inhibited by the lack of reprocessing capacity which seriously restricts the amount of plutonium available for use in thermal reactors. However, it is felt that no time should be lost in demonstrating that plutonium can be used as a fuel for LWR's with effective security arrangements and safeguards and the Belgian policy is for the enlargement of present fabrication facilities as soon as warranted by the availability of plutonium so as to be able to follow the demand.

TABLE 2

MIXED OXIDE FUEL IRRADIATION EXPERIENCE IN FORATOM COUNTRIES

Country	Reactor	No of Assys	No of Pu Rods	Date Loaded	Date of Discharge	Mean Irrad^{n} at Discharge or to date MWD/te
BELGIUM	BR3 (10 MWe PWR)	1	12	1963	1964	3000
		1	37	1966	1970	25000
		2	36	1969	1974	34000
		13	240	1972	1975	21000
		9	212	1972	1978	24500
		31	348	1976	1980	
BELGIUM/ FRANCE	CHOOZ (280 MWe PWR)	4	160	1974	1977	32000
		2	416	1975	1978	29000
GERMANY	KWO (345 MWe PWR)	1	180	1972	1974	16000
		8	1440	1973		30000
		4	720	1974		20000
		8	1440	1975		8000
		4	720	1976		
	KRB (250 MWe BWR)	16	540	1974	1978	16000
		24	840	1975	1979	9000
		24	840	1976	1980	3000
	KAHL (15 MWe BWR)	1	36	1966		16000
		4	144	1969		
		16	144	1971		
		1	36	1971	1977	15000
		1	36	1973	1977	20000
		18	162	1973		
		18	144	1975		
	MZFR (50 MWe PHWR)	8	296	1972		13000
HOLLAND	DODEWAARD (54 MWe BWR)	2	30	1971	1974	21000
		4	57	1973	1977	11000
		1	12	1974	1978	7500
ITALY	GARIGLIANO (160 MWe BWR)	12	608	1968	1975/77	21000/25000
		4	252	1970	1977	24000
		46	1426	1975	1981/82	7500
	TRINO (257 MWe PWR)	8		1976		
SWEDEN	OSKARSHAMN (440 MWe BWR)	3	51	1974	1979	11000
	AGESTA (12 MWe PHWR)	4	60	1966	1969	11000
UK	WINDSCALE (32 MWe AGR)	4	192	1964		20500
	WINFRITH (100 MWe SGHWR)	1	36	1969		12000

France

The national strategy is for the utilisation of all the plutonium produced in the French thermal reactors in the fast breeder programme but there has been some irradiation demonstration of plutonium fuels in PWR's and in the event of serious delays in establishment of commercial fast reactors, the possibility of plutonium recycle in thermal reactors is not excluded.

Federal Republic of Germany

For more than ten years, the German Government has sponsored research and development into not only the fast breeder fuel cycle but also into plutonium recycle in LWR's. In this period about 20 tonnes of mixed oxide fuel has been fabricated for irradiation demonstration in various FRG reactors and it is considered that the fuel fabrication and reactor technologies for plutonium recycle have been established. It is anticipated that in the medium term there will be a surplus of plutonium in excess of the fast breeder reactor requirements and the burning of plutonium in LWR's is seen as a strategy for minimising the amount of accessible plutonium from considerations of security (8). However, whilst the Alkem commercial prototype mixed oxide fuel fabrication plant has a capacity of about 40 tonnes per annum and there is confidence that this could be scaled up, without serious commercial or technical risks, it is intended to co-locate the production scale plant with the German reprocessing plant (9) so that it will not be on line before the late 1980's (10).

Holland

There has been a successful development of the Vibrasol fuel concept which is based on oxide spheres made by a sol gel process. This "wet" fabrication route is claimed to have advantages for mixed oxide fuel fabrication and to be very suitable for incorporating at the tail end of a reprocessing plant. However, the project has been abandoned due to the lack of a home market and the relative inaccessibility of external markets.

Italy

Extensive research and demonstration programmes have been carried out by ENEL and CNEN and on the basis of this successful experience, plutonium can be considered as an alternate fuel for LWR's. Substantial quantities of plutonium fuel assemblies were loaded into the Garigliano BWR (¼ core, Pu island) in 1975 and the Trino PWR in 1976 but further extension of plutonium recycle has been prevented by the crisis in reprocessing capacity and the resultant shortage of plutonium. In the medium term, therefore, the extent of plutonium recycle will be determined by fast reactor development requirements and the actual production of plutonium from reprocessed fuel. However, it is emphasised that in the present transitional period there should be no slowing down of planned research and development and the qualification of individual reactors.

Spain

It is felt that plutonium recycle would enable a better use of energy resources, saving uranium and separative work and thus contributing to a reduction of energy dependence on other countries. In view of this, the future fabrication of mixed oxide fuel has been considered but due to the continuing delay in reprocessing availability, the question of plutonium recycle in Spain will not arise before the early 1990's.

Sweden

The Swedish utilities plan to recycle plutonium in thermal reactors and some related design and development work is in hand but there are no plans for commercial mixed oxide fuel fabrication in Sweden so it is envisaged that rod manufacture would be sub-contracted to a foreign firm. However, due to the uncertainties in reprocessing it is difficult to predict when plutonium recycling will start in Swedish reactors.

Switzerland

In general the Swiss utilities are in favour of plutonium recycling but they are conscious of possible regulatory and environmental difficulties and it is felt that a decision on recycle in Switzerland will have to await appropriate development in other European countries and the US.

United Kingdom

Up to the present, the policy has been to store plutonium for utilisation in the fast breeder reactor and the research and development programmes have been related to this objective although in the 1960's about 3 tonnes of low enrichment plutonium fuel was manufactured at Windscale for irradiation demonstration in various thermal reactors in Europe. The policy has recently been reviewed by BNFL and the UK Generating Boards and whilst circumstances can be envisaged which might lead to a change, notably further considerable delays in the fast reactor programme, the earliest date for large scale recycling of plutonium in thermal reactors is considered to be the early 1990's.

EEC

Late in 1974 the Commission of the European Community launched a Programme of Research and Development for the promotion of plutonium recycle in LWR's with a budget of about $4M for the period 1975 to 1978. The programme covers surveys of plutonium utilisation in Europe, assistance with funding of post irradiation examination of plutonium fuels, and safety and control studies as well as a study of environmental problems in the European context similar to, but on a smaller scale than the US GESMO study which could assist in establishing an independent European position on plutonium recycle.

5. CONSTRAINTS ON THE ESTABLISHMENT OF PLUTONIUM RECYCLE

Reactor Control and Safety

The reactor physics calculation methods in use for enriched uranium cores have been shown to be applicable to plutonium recycle in LWR's in the demonstration irradiation programmes carried out in the UK, Belgium, Italy and Germany, though in some respects the accuracy of the calculations needs to be improved. Further studies are required on fuel management and accident analysis with Pu recycle in a 1000 MWe scale reactor, including an assessment of the control rod requirements to determine the amount of plutonium which can be recycled in an existing reactor. Absence of a large scale demonstration programme throws emphasis on sensitivity type calculations to establish confidence in these studies and a programme of such studies on the control and safety of Pu fuelled PWR's is being sponsored by the EEC.

For the loss of coolant accident (LOCA) calculations, specific data on fuel performance are required, eg densification, thermal conductivity and swelling and it will be necessary to substantiate to the satisfaction of the Regulatory Authorities that the UO_2 data currently being used is applicable. In this connection the EEC sponsored PIE programme on LWR plutonium fuels should provide considerable data on a variety of fuels from different manufacturers, and the EPRI Plutonium Fuel Study, with which some European organisations are associated, has already shown that mixed oxide pellets can be produced with as good stability against densification as UO_2.

In summary therefore, whilst some improvement in calculational methods and some further data on fuel behaviour are necessary, specific to plutonium enriched PWR fuels, there are no major technical constraints in this area. Some further consideration does, however, need to be given to the choice of the mode of recycling, ie all plutonium or plutonium island fuel assemblies and the proportion of the reactor cores to be taken up with plutonium fuel, in order to achieve the optimum between considerations of reactor operation and the other parts of the fuel cycle notably reprocessing.

Fuel Fabrication

The position on mixed oxide fuel fabrication in Europe is discussed in Section 2 where the point is made that the high radiotoxicity and the radioactivity of plutonium impose considerable environmental constraints on the design and operation of production scale plants. This means that before committing the capital expenditure on such plants there must be adequate confidence in being able to meet these constraints and in particular the minimising of radiation doseage to the operators and the arisings of plutonium contaminated waste. Consequently although prototype commercial plants have been successfully established, the leadtime for the design and construction of large new mixed oxide fuel fabrication plants will be long. In 1976 an IAEA panel of experts estimated the period between decision planning and production at 7 years (11) and unless there is a radical improvement in the current trends in respect to public and Governmental acceptance of nuclear power it would not be unreasonable to estimate for new sites regulatory delays might increase this period to 10 years.

Reprocessing

Up to the present time, the only substantial reprocessing capacity in Europe has been that in France and the UK for the reprocessing of metal fuel from the first generation of gas cooled stations and the plutonium arising has essentially been stored for eventual use in fast breeder reactors. It is not surprising therefore that in their contributions to this paper, most of the FORATOM countries cite lack of reprocessing capacity as the major reason for delays in the establishment of plutonium recycle in Europe. Assuming, however, that reprocessing capacity in Europe does become available in the 1980's as envisaged in the Appendix and the stocks of plutonium do permit consideration of recycle in thermal reactors, there are specific technical problems related to the eventual reprocessing of mixed oxide fuel.

The first technical problem arises from the higher residual plutonium content in irradiated mixed oxide fuels which means that in a plant designed for UO_2 fuel the throughput is reduced substantially from criticality and chemistry considerations, with consequent operational complications and increased unit costs. Some alleviation may be obtained by dilution with UO_2 fuel but this also has economic penalties and any substantial programme of recycle would require additional specific reprocessing development and the provision of special purpose plants. A second problem stems from the fact that above a certain concentration of PuO_2, ie about 40 per cent (12), mixed oxide does not dissolve in the nitric acid normally used in reprocessing plants for taking the fuel into solution and consequently heterogeneous fuel with plutonium rich areas can leave an unacceptable level of solid residues in the dissolver. In practice as the nominal plutonium content of the new fuel is normally less than 5 per cent, this problem can be overcome in fuel fabrication by suitable choice of starting materials and attention to the route so as to achieve either a solid solution of PuO_2 and UO_2 or a finely divided mixture. However, this problem does contribute to the reluctance of fuel reprocessors to undertake the reprocessing of mixed oxide fuel particularly in a situation of overall capacity shortage and when, in the future, they are prepared to undertake such reprocessing they will probably require the qualification of the specific fuel by means of a dissolution test with a stringent limit on the level of solid residues.

It is clear, however, that the absence of immediate reprocessing capacity for mixed oxide fuel need not prevent the introduction of plutonium recycle, as irradiated fuel may be stored for several years with little economic penalty and the quantity of plutonium so held up would be small in relation to that arising from the reprocessing of UO_2 fuel. Nevertheless before embarking on programmes leading to the establishment of plutonium recycle on a substantial scale, electrical utilities and/or Governments will want assurance that the above problems can be solved and a commitment from reprocessors that the appropriate reprocessing capacity will be made available on a reasonable timescale and at acceptable cost.

6. PROSPECTS FOR PLUTONIUM RECYCLE IN EUROPE

It is generally accepted that full recycle of plutonium in LWR's would reduce uranium ore requirements by about 15 per cent and separative work requirements by about 20 per cent but the resultant savings are offset by the cost penalties incurred in the fabrication and reprocessing of mixed oxide fuels as compared with conventional UO_2 fuels. In the recent GESMO

study (12), assuming ore and separative work costs of $28/lb and $75/kg respectively, the overall saving for complete recycle as compared with no reprocessing and no recycle is estimated at about 8 per cent which is only of the same order as the uncertainties in the estimate. The incentive will, of course, increase with increase in uranium ore and separative work costs but even if the figures assumed above were doubled the estimated saving would still be only about 13 per cent so it seems unlikely that there will be any dramatic improvement in the economics of plutonium recycle within the next decade. On the other hand, if reprocessing capacity is established as envisaged, there will be a substantial and increasing surplus of plutonium commencing in the late 1980's and particularly if there is any further fallback in the introduction of the fast breeder reactor, there could be a growing incentive for the recycle of plutonium in order to utilise "indigenous" resources and from considerations of security in order to minimise the amount of accessible plutonium outside reactors, as is recognised by the German strategy. (8) For similar reasons of security it may become policy for the provision of mixed oxixe fuel fabrication plants on reprocessing sites so that plutonium can be returned to customers as reactor fuel.

Considering the status of plutonium recycle technology and the position in the individual Foratom countries, it is clear that although the situation in Britain and France is somewhat different the main constraint on the establishment of plutonium recycle in Europe has been the lack of reprocessing capacity for UO_2 fuel and hence a shortage of plutonium. This situation will not be rectified before the late 1980's but then, assuming that the political/environmental climate permits, before promoting plutonium recycle, utilities will want some assurance from reprocessors on the eventual reprocessing of irradiated mixed oxide fuel. Assuming that this is forthcoming, the main constraint will be on mixed oxide fuel fabrication as the existing plants could only sustain a few GW of generating capacity and this limitation will persist until the first production scale plant is operating. Consequently, as it has been argued that the lead time from planning to operation of such a plant on a new site is now about ten years, it seems unlikely that plutonium recycle could be established on a substantial scale in Europe before the late 1980's, even if a clear incentive was recognised now.

This timescale is consistent with the German plans for the association of a mixed oxide fuel fabrication plant with their first reprocessing plant and none of the other countries have plans for a new fabrication plant on an earlier timescale with the possible exception of Belgium where Belgonucleaire intend to build a new plant as soon as warranted by the availability of plutonium although on the basis of the estimates given in the Appendix, this will not be before 1985.

7. SUMMARY AND CONCLUSIONS

Although the fuel fabrication and reactor technologies are well established in a number of FORATOM countries there is unlikely to be substantial plutonium recycle in thermal reactors in Europe before the early 1990's by which time it is assumed that substantial reprocessing capacity will have been established and the necessary plutonium should be available.

The incentive for recycle at that time will depend on the status of the fast breeder reactor and the position in respect to cost and availability of uranium ore although in some countries there might be a straightforward desire to utilise an available resource and, as discussed, there could be a case for recycle on security considerations.

It is concluded, therefore, that the option of plutonium recycle may be required for the early 1990's and in view of the long lead time for the establishment of mixed oxide fabrication plants, this option will not be available unless planning decisions are taken as long as ten years in advance. The following important areas for international collaboration have been identified:

(1) The definition of a standard base material for plutonium fuel fabrication, which is acceptable from considerations of reprocessing, storage, transport and security.

(2) The identification of the optimum modes of recycle from considerations of reactor operation and the other parts of the fuel cycle.

(3) The resolving of the technical problems of reprocessing mixed oxide fuel and agreement on the timescale for provision of capacity.

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APPENDIX

ESTIMATED CUMULATIVE PLUTONIUM PRODUCTION IN EUROPE FROM OXIDE FUEL

Year	High Power Growth/High Reprocessing Capacity				Low Power Growth/Low Reprocessing Capacity			
	Reactor Installation GWe	Reprocessing Capacity teU	Pu Discharged in Fuel te Pu	Pu Reprocessed te Pu	Reactor Installation GWe	Reprocessing Capacity teU	Pu Discharged in Fuel te Pu	Pu Reprocessed te Pu
1975	21	-	1	-	21	-	1	-
1980	69	2100	20.5	12.5	65	1500	19.8	9.1
1985	169	10400	88.2	63.4	136	6900	80.7	41.9
1990	291	38500	245	234	225	24300	206	147.6

Source

Reprocessing of Spent Nuclear Fuels in OECD Countries SEN/NELT(76)14 (Draft) December 1976

ESTIMATED CUMULATIVE PLUTONIUM SURPLUS IN EUROPE

Year	(a) Pu from U Metal te	(b) Pu from U Oxide te	(c) FBR Requirement te Pu	Pu Surplus te
1975	10	-	2.5	7.5
1980	26	9	17	18
1985	41	42	38	45
1990	56	148	102	102

Sources

(a) Plutonium Production and Utilisation Forecasts in Europe by B Haijtink EUR 5479e March 1976
(b) Reprocessing of Spent Nuclear Fuels in OECD Countries SEN/NELT(76)14 (Draft) December 1976
(c) EEC Fast Reactor Installation Programme as given in Source (a), but delayed 3 years