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WISE-Paris
31-33, rue de la Colonie
F-75013 Paris
Tél. : France : 01 45 65 47 93
International : +33 1 45 65 47 93
Fax : France : 01 45 80 48 58
International : +33 1 45 80 48 58
e-mail : WISE-Paris@globenet.org

THE DUTCH PLUTONIUM DEAD END

Mathieu Pavageau, Research Associate
Mycle Schneider, Director

October 1997

Commissioned by Greenpeace-Netherlands

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Please note: If not otherwise specified, all weights of nuclear material are given in metric tonnes heavy metal (without taking into account the weight of the oxide if the material is in an oxide chemical form) and abreviated MT. If not specified otherwise, all quantities of plutonium are given as total plutonium (taking into account all plutonium isotopes).

INTRODUCTION

Even though the Netherlands have not launched a large nuclear programme, and in particular did not order any nuclear power plant after 1973, both electricity utilities operating the only two nuclear reactors started a plutonium programme, in the framework of a European collaboration: both utilities signed reprocessing contracts; and the Dutch Cooperation of Electricity Producers (SEP[1]) owns shares of a European Fast-Breeder Reactor consortium. The objective of the plutonium programme was originally to produce plutonium in reprocessing plants to be used in breeder reactors.

There are only two nuclear power plants in the Netherlands of which one is still operated. The electricity utility GKN[2] operated the 57 MWe boiled water reactor (BWR) at Dodewaard, which went critical in 1968. At the beginning of October 1996, SEP announced that the Dodewaard nuclear power plant would be definitely shut down by March 1997, even though a large investment had been made recently to upgrade the safety of the plant. The reason would be of economic nature. The plant had previously been planned to be shut down by 1 January 1995, then by 2004. The plant was effectively shut down by the end of March 1997[3].

The electricity utility EPZ[4] operates the **only operating nuclear power plant**, the 459 MWe pressurised water reactor at **Borssele**, which went critical in 1973. This plant is now planned to be shut down by 2003.

The objective of this report is to analyse management options of Dutch plutonium. Unlike other countries, the Netherlands have to manage a large quantity of plutonium while this material has no use in the Dutch nuclear industry. The Netherlands have participated in European nuclear programmes and

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[1] SEP stands for NV Samenwerkende Elektriciteitsproduktiebedrijven.

[2] GKN stands for NV Gemeenschappelijke Kernenergiecentrale Nederland.

[3] *Nucleonics Week*, 3 April 1997.

[4] EPZ stands for NV Elektriciteitsproduktiemaatschappij Zuid-Nederland. EPZ was called PZEM until 1990.

collaborated in national nuclear programmes of other countries for the last thirty years. One of the results of this collaboration is the accumulation of inventories of plutonium, either plutonium inside spent nuclear fuel or separated plutonium produced in the reprocessing plants. This inventory of plutonium will definitely not be used in the Netherlands since the only remaining reactor will be shut down by 2003 (at the latest), without having used plutonium fuel.

Some countries which have accumulated separated plutonium stockpiles are trying to reduce the stockpiles by using plutonium to produce a nuclear fuel called MOX (mixed oxides containing both uranium and plutonium) for standard nuclear power plants. These countries are for instance France, Japan or Germany. The question concerning these countries, is whether the inventory of plutonium is still increasing or being reduced, today and in the future, in other words if the use of separated plutonium for the production of MOX fuel requires a larger or smaller quantity of separated plutonium than what is produced in the reprocessing plants. Currently, neither of these three countries are producing MOX fuel at a higher rate than that which would be necessary for a decrease of plutonium stockpiles: stockpiles of separate plutonium are increasing. For other countries, like the Netherlands, Spain or Italy, the problem is more consequent. These countries have produced and accumulated stockpiles of separated plutonium but this material has no use for neither of them.

The **first** part of the report gives details on the Dutch participation in the Fast-Breeder Reactor and reprocessing programmes in Europe which have caused the plutonium surplus problem.

The **second** part of the report presents the liabilities associated with the management of plutonium, which are of different orders. The use of plutonium in the civil nuclear industry raises nuclear proliferation concerns due to the possible diversion of the material for military uses. The radiotoxicity and the fissile characteristics of plutonium make it the most dangerous material to manage in the nuclear industry.

The **third** part is a description of the management of plutonium in the countries which have stockpiles of separate plutonium. Particular emphasis will be made on the potential interest of these countries to increase their stockpile through the purchase/lease of plutonium from another country.

The **fourth** part gives an estimate of the inventory of Dutch plutonium and discusses how this plutonium has been managed and what final destination can be found for it. The fact that EPZ has recently signed contracts for the reprocessing of the remaining spent fuel to be discharged from the Borssele plant and the justification and consequences of this engagement will be analysed.

1. THE PLUTONIUM INDUSTRY

In Europe, reprocessing - the better term is "plutonium production" - was first developed by France and the United Kingdom during the 1950-1960s to produce plutonium for the military programmes.

In 1957, the European Atomic Energy Community (Euratom) was created and in 1967, Euratom was incorporated in the European Economic Community (EEC). The objective of Euratom was to enable the development of a nuclear energy industry which would enhance the economic development of the European Community. However, the nuclear industry within the three largest civil nuclear programmes, Germany, France and the United Kingdom, did not develop their nuclear power plants as a community and each country independantly created separate reactor designs. The European collaboration focused more on long-term research and develop-ment, and in particular on the development of reprocessing and of fast-breeder reactors, that is on the plutonium industry. In the framework of this European collaboration, smaller countries like Belgium, Italy and the Netherlands, participated in large European research programmes, even though the possible applications of this research would be even later for them than for the countries which had were already advanced in the development of a national nuclear power plant programme [Giesen88].

The fast-breeder technology and its complementary reprocessing industry[5] were chosen to be developed as a solution to energy and electricity shortages which were planned for the end of the century. Also, the oil crisis in 1973 emphasised the aim to develop so-called energy independence. Twenty years later, the gigantic increase in electricity consumption forecasted for the end of the century has not taken place. Production overcapacities have been built up all over Europe.

A main reason given by the nuclear industry for developing the breeder reactor was the high price of uranium and its expected further increase. Even in the early days the industry realized that it needed to keep the momentum of civil nuclear technology going by developing new technology, such as breeder technology. Because of the military nuclear-weapon programmes, the politicians were easily persuaded. If there had been no demand for nuclear weapons, nuclear technology would not have prospered.

1.1. The Failure of the Fast-Breeder Reactor Programme

The fast-breeder reactor (FBR) programme has been a failure, both as a community programme and in national development schemes. Projects for the construction of other reactors in France (Superphénix-2) and in Germany (SNR-2) were abandoned. The future of the French 250 MWe Phénix plant is in the hands of the safety authorities who will decide before the end of 1997 if current safety upgrades are sufficient for further licensing. The Superphénix reactor, which had been officially converted into a research reactor, had its license withdrawn in February 1997 and the new Jospin government decided to abandon

[5] **What is reprocessing?** Reprocessing is a process which chemically dilutes the spent nuclear fuel to separate out its different components. Spent fuel reprocessing produces separate plutonium, separate uranium, and nuclear waste. Reprocessing is the only way to produce separate plutonium.
What is the specificity of a Fast-Breeder Reactor? FBRs can theoretically produce ("breed") over the long run more plutonium than they consume. However, these reactors require plutonium in the core to start with and the "doubling time" (time necessary to produce enough plutonium to fuel a second breeder reactor) might be substantially longer than the life time of the reactor...

the reactor entirely. It should be understood that this was a firm decision announced in the governments general policy statement (see below).

The following table gives the crossed participation of the different European utilities in the FBR programmes. The Netherlands participated in the programmes through the Germany-based SBK[6], of which SEP owns 14.75%.

Table 1: Crossed Participations of European Utilities in the Fast-Breeder Projects, *with Dutch Participation (from SEP)*

Company	Share in NERSA (Superphénix)	Share in SBK (Kalkar)	Share in ESK (SNR-2)
EDF[7]	51%	0%	16%
ENEL[8]	33%	0%	33%
SBK	16%	100%	51%
TOTAL	**100%**	**100%**	**100%**
SEP participation in project	***2.36%***	***14.75%***	***7.52%***

(Source: Mot.Col.86, SEP, SBK)

According to information published by SEP, SEP would own a 1.7% share of NERSA, the builder-operator of Superphénix. However, this figure does not correspond to the share which can be calculated with the participation of SEP in SBK and the participation of SBK in NERSA (14.75% of 16% is 2.36%).

Superphénix

Status of the reactor

The Superphénix FBR was the second commercial FBR to be built in France. It succeeded the 250 MWe Phénix reactor which went critical in 1973. The Superphénix is a 1,200 MWe reactor, and is operated by NERSA. It has the worst capacity factor of all commercial reactors, having produced 8.2 TWh from the time it went critical in 1985 to 24 December 1996 (date of its final shut down), which corresponds to a 7.5% life time capacity factor. According to the collaboration agreements[9], about 0.075 TWh of this electricity was supplied to the Netherlands. In 1994, since the reactor had been shut down for more than three years, a new licensing procedure with a public enquiry was necessary. The operator NERSA requested a new license for a change of the status into a research reactor, with approval from the French government.

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[6] SBK stands for Schnell-Brüter-Kernkraftwerksgesellschaft.

[7] EDF stands for Electricité de France, the French domestic electricity utility.

[8] ENEL stands for Ente Nazionale per l'Energia Elettrica.

[9] SEP has been attributed 11 MWe of the 1,200 MWe of the Superphénix plant. This share corresponds to 0.9%, which is lower than the 2.6% share that SEP has in NERSA, the operator of Superphénix. No information has been found to explain this discrepancy. Source: personnel communication Diederik Samson, Greenpeace-Netherlands.

The reactor was assigned three research objectives, which are:

- assess if the reactor can be used to burn long-lived high-level radioactive waste (actinides);
- assess if the reactor can be used to consume ("burn") plutonium (FBRs were first designed to produce *more* plutonium than what they consume);
- assess to what extent the reactor can produce electricity.

All three objectives should have been assessed without modifying the safety of the operation of the plant.

The new 1994 license was attacked in the Courts on the grounds that it authorised the modification of the status of the plant to that of a research reactor, while this had not been made clear in the documents which were submitted during the public enquiry. Consequently,the *Conseil d'Etat,* the highest administrative court in France, cancelled the 1994 license in February 1997. There were disagreements inside the government which was in power until 1 June 1997 as to how the license could be renewed. The Minister of Industry clearly stated he would want the plant to have a new license without going through another public enquiry, which normally should be compulsory. The Minister of Environment stated on the contrary that she was in favour of a new public inquiry. The legislative elections on 1 June 1997 unexpectedly changed the government and named the Socialist Lionel Jospin Prime Minister. During his General Policy Declaration before the National Assembly, Thursday 19 June 1997, Prime Minister Lionel Jospin announced the "abandonment" of Superphénix:

"In the field of high technology, where sometimes great risks are involved, I wish for inspection measures to not be confused [or merged] with those which concern operation. If the nuclear industry is an important asset for our country, it must not exempt itself from democratic rules, nor pursue projects of excessive cost and uncertain sucess: this is why the fast-breeder reactor which is called "Superphénix" is to be abandoned."

The fact that the Superphénix license had been withdrawn prior to the political decision means that it does not need any additional administrative act to keep the reactor down. Currently, the organisations and government agencies involved analyze various fuel and sodium unloading scenarios.Fuel for the reactor.

Two mixed oxide (MOX) cores containing plutonium and uranium oxides have already been produced for the Superphénix reactor. The first core of Superphénix contained 4.8 tonnes of fissile plutonium and 5.9 tonnes of total plutonium[10]. We suppose that the second core, which was produced before the status of the reactor was changed to that of a research reactor, is the same as the first.

[10] Personal communication with Christian Cartouze, spokesperson of Superphenix power plant, Malville, 18 December 1996.

Kalkar and SNR-2

The Kalkar SNR-300 Fast Breeder Reactor

The Kalkar SNR-300 reactor in the Land of North Rhine-Westphalia was the first commercial FBR to be built in Germany. The project was initiated in 1973. This reactor was to be operated by the international consortium SBK (Cf. table 1). However the Government of the Land refused to authorize fuel loading and the reactor was abandoned in 1991, at a time when the reactor was entirely built[11].

The first core of the reactor had already been produced. The core is a mixed oxide (MOX) core containing both uranium and plutonium oxides. The core was produced partly in Belgium (82 fuel elements) and partly in Germany (123 fuel elements).

In 1993, a contract was signed between SBK and the UK Atomic Energy Authority to store and, eventually, to reprocess 205 non-irradiated fuel elements from the Kalkar reactor. In 1993, 82 of these elements had already been flown from Belgium to Dounreay, United-Kingdom. The remaining 123 elements, containing about one tonne of plutonium, were in store at the Siemens plant at Hanau, Germany. Apparently the German party has cancelled the reprocessing contract for the fuel which was and still is in store in Germany.

During 1996, the German government gave information on the German plutonium inventory. In particular, it was confirmed that the 123 fuel assemblies which had been planned for the Kalkar SNR-300 FBR were still stored at the Hanau site, and were planned to be moved to the Ahaus interim storage facility. The German utility RWE, which also owns about eight tonnes of separated plutonium, and which has the largest share in SBK, "does not want to pay for expensive re-reprocessing"[12].

The destiny of the Kalkar FBR is very ironic, in particular for the Dutch participants in the project. Mr. Henny van der Most, a Dutch business man, has started to transform what remains of the Kalkar plant into an amusement park.

SNR-2: the Failure of the Successor to the Kalkar SNR-300

At the time when SNR-300 was developed, a successor to SNR-300 was planned in the framework of the European collaboration. Simalar to Superphénix, this demonstration FBR would have had about 1,200 MWe electric output. Ownership would have been by a company called ESK, owned 51% by SBK, 33% by ENEL and 16% by EDF (Cf. table 1). The SNR2 reactor was never developed because of the general failure of the fast breeder systems. It was mentioned that German utilities stated they would only build SNR-2 if it were as economic as a German PWR [Mot.Col.86]. The decision not to build this reactor shows that very early utilities realized that FBRs do not have any industrial future.

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[11] *Nucleonics Week,* 28 March 1991.

[12] *Nucleonics Week,* 15 August 1996.

Dutch Participation in the Fast-Breeder Reactor Programmes

This part gives an overview on the Dutch investment in the breeder programme, through the utilities or directly from public funds. Following are elements on the quantities of Dutch plutonium which were produced or used in the framework of this collaboration.

Dutch Financial Participation in the FBR Programmes

The Dutch share in the Kalkar SNR-300 programme was 7.5% and has cost about HFL 1 billion (1986 currency) to the Netherlands, of which three quarters were financed by the Government [Mot.Col.86]. The 7.5% share in the costs of operation quoted here is smaller that the 14.75% share of SEP in SBK (Cf. table 1).

As of 1986, officially the Dutch contribution to the Superphénix programme amounted to HFL 25 million, while the contribution according to its share in SBK should have been much higher [Mot.Col.86]. No explanation was given to the reasons of this smaller contribution.

In 1986, the main incentives for the Netherlands to continue with the European FBR collaboration were:

"(i) to participate in a long-term European energy development strategy that has promise of economic power production and energy independance for Europe;

"(ii) to take advantage of collaborative development of high technology capability, as in the past a small percentage input would provide access to 100% of expertise and experience generated." [Mot.Col.86]

These incentives are no longer valid. The European FBR collaboration is limited to the joint management of the Superphénix site, and the technology which the Dutch have had access to will mostly be useless since they will not build any new FBR. The Dutch participation in the European collaboration has been basically wasted investment.

Since neither SEP nor the Dutch government was responsible for the decision which condemned Kalkar, they could have insisted to be reimbursed of their lost investment. According to Dutch representatives, in 1991, "the German decision to stop the Kalkar project [was] an infringement of the German obligation to connect the Kalkar reactor to the grid" and the Dutch government did not want to renounce its right to compensation claims[13]. Belgium has requested in 1991 to be reimbursed of its investment in Kalkar[14]. However, it seems in 1997 as if no compensation has been allocated.

It was announced in 1995 that both ENEL and EDF would sell their shares of ESK. No information was given concerning the continuation of Dutch participation in this project.

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[13] *Power in Europe,* 23 May 1991.

[14] *Enerpresse,* 22 July 1991.

Regarding the **Superphénix** reactor, the situation is quite different. The reactor was licensed and operated, but incidents plagued its operation and much less electricity was generated than planned. In July 1994, the license decree of the reactor was modified and Superphénix was then considered a research reactor[15], one of its objectives being to assess the capacity such reactor has to consume plutonium instead of producing surplus.

Since the first objective of the operation of the reactor was no longer to produce electricity, foreign utilities which had shares in the NERSA operator - and who were not consulted prior to the modification of the reactor operational destination - required compensation. On 15 September 1995, an agreement was reached between EDF and the foreign participants requiring that the participants continue to pay their share of the operational costs but guaranteeing that they would receive until the end of year 2000 a certain amount of electricity, of which 0.13 TWh for the Netherlands[16]. This amount corresponds to the quantity of electricity the participants would receive if the reactor were to have a 60% load factor until then. If the reactor does not generate this electricity, EDF has agreed to deliver this electricity from its other reactors. This agreement will be questioned and renegotiated for eventual further collaboration after year 2000, or if the Superphénix plant is stopped for more than one year before then [C.Comptes96].

Dutch Plutonium Participation in the European FBR Programmes

The first core for the **Kalkar reactor** contained 1,385 kg of fissile plutonium, which has been estimated to be equivalent to about 1,800 kg of total plutonium [Albright97]. The 82 fuel elements for Kalkar which were produced in Dessel, Belgium, were sent to the UK for storage and reprocessing. The other 123 fuel elements are still stored at Hanau.

The Dutch share in Kalkar is 14.75%. Consequently SEP should have provided the necessary plutonium for about 30 fuel elements, corresponding to about 265 kg plutonium. However, according to published information, the quantity of Dutch plutonium provided for Kalkar was 174 kg in 1979, which corresponds to 9.6% of the total plutonium (Cf. table 11). No information has been put forward to explain the discrepancy.

It can be supposed that the 174 kg Dutch plutonium were incorporated in the Kalkar fuel produced in Belgium. Therefore, this plutonium would now be stored in the UKAEA Dounreay site.

Since SEP owned a 1.7% share of NERSA, it should have contributed the same share of plutonium for the two cores which were produced for the **Superphénix reactor**. Each of the two 39.3 MT cores contained 5,900 kg total plutonium, together with depleted uranium. Consequently, SEP should have

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[15] This led the German Weekly *Die Zeit* to the appropriate statement that to transform Superphénix into a research reactor is like transforming the Eurotunnel into a wind channel for aerodynamic experiments.

[16] The total amount of electricty EDF will supply the foreign shareholders of NERSA is 14.5 TWh. According to the general scheme SEP would receive about 0.9%.

contributed about 100 kg plutonium for each core. The first core has produced 8.2 TWh, which corresponds to a burnup rate of 21,700 MW.d/MT core. We have not found any figure on the amount of plutonium which has been produced in the fertile part of the fuel which is around the core. In any case, because the reactor was in a plutonium producing configuration, the quantity of plutonium produced in the fertile fuel is greater than the quantity which was consumed in the core. However, according to the published information in the Netherlands, 68 kg and an additional 47 kg have been transferred for use in Superphénix, apart from 328 kg which have been sold to the Italian ENEL which owns 33% of Superphénix (Cf. table 1).

The total quantity which has been transferred for use in Superphénix and has not been sold to ENEL (115 kg) is less than the quantity of plutonium SEP should have contributed for both cores, which amounts to about 200 kg. It must be noted that some of these 115 kg of plutonium have been introduced in the first core of Superphénix and has been bred during the operation of the reactor, and now corresponds to a somewhat larger quantity because of the production of plutonium in the fertile fuel.

We have not been able to find much information on the conditions of the plutonium transfers for use in the FBRs. Because of its participation in SBK and NERSA, SEP was entitled to supply plutonium for both Kalkar and Superphénix. However, according to Governemental information (Cf. table 11), the plutonium which has been used in Superphénix has been sold to COGEMA, to ENEL and to SBK/NERSA. No precise information has been given on requirements concerning the further use of the material, and in particular legally binding engagements that it is only used, directly and indirectly in civil programmes.

1.2. The Reprocessing Industry

> *"A comparison of actual costs (as of today) shows that costs for reprocessing of spent fuel are about a factor of 1.8 higher than for long term interim storage and final disposal without reprocessing."*
>
> P. Bauder (Badenwerk AG) and W. Blaser (Kernkraftwerk Philippsburg GmbH), during the Fourth International Conference on Nuclear Fuel Reprocessing and Waste Management, RECOD'94, London, 24-28 April 1994.

At the beginning of the 1970s, in order to produce plutonium for the future fast-breeder reactors, the different European countries signed reprocessing contracts with the British BNFL and the French COGEMA. Japan signed similar contracts. The reprocessing industry, which needed considerable investments to be developed to the commercial scale, was boosted by these foreign contracts. At the time, reprocessing was chosen for significant quantities of spent fuel in Europe and in Japan. On the other side, in 1976 President Carter put an end to a possible reprocessing programme and with it to the development of commercial FBRs in the US.

Reprocessing contracts for Dutch spent fuel concern both spent fuel from the Borssele and the Dodewaard plants.

Reprocessing Contracts for Borssele Spent Fuel

COGEMA has two reprocessing plants at La Hague: The first one called UP2 (for "plutonium factory 2"), started reprocessing oxide fuels in 1976 and has been devoted mainly to reprocessing of French nuclear fuel since 1990.

The second plant called UP3, was financed entirely by COGEMA's foreign customers (in principle[17]) and started operations in 1990.

The UP2 Contracts

The first contracts between utilities and COGEMA were signed at the beginnning of the 1970s. At the time the UP2 reprocessing plant already existed even though it did not yet reprocess oxide spent fuel (from PWRs or BWRs) but magnox fuel from the French reactors. These first contracts corresponded to fixed quantities of spent fuel and to a fixed cost. One of these contracts was signed for the reprocessing of 85 MT spent fuel from the Borssele PWR. This spent fuel was reprocessed at the UP2 plant, before the year 1990.

The UP3 Contracts

Additional contracts were signed with foreign customers in 1977 and 1978 in the form of a very specific type of service contract. Through these, COGEMA found the necessary funds from 30 foreign utilities in 7 countries, of which EPZ,

[17] There is doubts as to whether COGEMA had all investment costs covered by its foreign clients. Probably it had to cover some of the unexpected surplus costs alone.

to build a new reprocessing facility, the UP3 plant. In return, COGEMA made available to these customers the planned reprocessing capacity of the plant during its first ten years of operation from 1990 to 2000. The basic contract ("base load customer contract") between COGEMA and its foreign customers contains identical terms and conditions for all contracting parties [Belg.Parl.92]. The UP3 contracts first of all mention a capacity of 6,000 Mt of spent fuel to be shared proportionally between the different contracting parties. EPZ took up 2% of the total quantity, amounting to 120 MT.

In 1983, COGEMA undertook, "in order to stabilize the average unit price for reprocessing" according to SYNATOM, to reprocess at least 7,000 tonnes over ten years at the UP3 plant [Belg.Parl.92]. In other words, investment costs had sky rocketed and COGEMA had found a way of covering at least a part of the overspendings. The extra reprocessing capacity was shared up on the same proportional basis as the 6,000 tonnes. The quantity of Dutch spent fuel to be reprocessed accordingly rose from 120 MT to 140 MT.

The Post-2000 Contract

Contracts to be fulfilled after the year 2000 (Post-2000 contracts) were signed between COGEMA and German utilities in 1990. Post-2000 contracts were so called *requirement contracts:* the quantities of fuel to be reprocessed are supposed to be adapted to the spent fuel production of a given reactor.

A similar post-2000 contract has been signed between SEP and COGEMA, corresponding to 156 MT[18]. According to the Dutch government, this corresponds to the total spent fuel production from the Borssele plant until its planned shut down in 2004.

Taking into account every reprocessing contracts, there is therefore a total quantity of 381 MT spent fuel from Borssele reprocessed or to be reprocessed at La Hague, which corresponds to the total spent fuel production of the plant.

Cost of Reprocessing Contracts

Because of commercial confidentiality, the real cost of the reprocessing contracts for the different customers is difficult to know. However, figures quoted by the Belgian Goverment are close to FF 7,500 per kg for the *base load customer* contracts [Belg.Parl.92]. This would correspond to about HFL 562.5 million (today's exchange rate) for the first two contracts representing 225 MT. It can be assumed that the contracts for post-2000 reprocessing have been agreed on a lower price, since the initial construction investment has already been shared between the customers and because utilities have questioned the reprocessing option on economic grounds in the mean time.

The following table shows the different reprocessing contracts which have been signed for spent fuel from the Borssele plant.

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[18] Kamerstukken II, 1996/1997, 24422, no. 1.

Table 2 Management of Spent Fuel from the Borssele plant (MT)

Reprocessing contracts	Corresponding quantity	Reprocessed spent fuel, *as of 1 March 1997*
COGEMA UP2 plant	85	85
COGEMA UP3 plant (baseload)	140	77
COGEMA UP3 plant (requirement)	156	0
TOTAL	**381**	**162**

(Sources: COGEMA94, COGEMA97, Baer97...)

According to the Dutch Government, the 381 MT spent fuel from the Borssele plant which is under reprocessing contracts is the total spent fuel production from the power plant.

Reprocessing Contract for Dodewaard Spent fuel

There are two reprocessing contracts for spent fuel from the Dodewaard plant. The first reprocessing contract concerns spent fuel which was sent to the Eurochemic and was reprocessed before the Eurochemic plant was shut down in 1974. The second contract represents a fixed amount of spent fuel which is to be reprocessed at the THORP plant operated by BNFL at Sellafield in the UK.

We make the hypothesis that no Dutch spent fuel has yet been reprocessed at the THORP plant, since the THORP plant started operations in 1994 and there is no incentive for BNFL not to process spent fuel from other foreign customers - in particular Japanese and German - which have a much higher tonnage under contract - or Switzerland which has a MOX fabrication contract with BNFL at the same site.

Table 3 Management of Spent Fuel from the Dodewaard plant (MT)

Reprocessing contracts	Corresponding quantity	Reprocessed spent fuel, *as of 1 March 1997*
Eurochemic plant	8	8
BNFL THORP plant	53	0
TOTAL	**61**	**8**

(Sources: Wolff96, Enerpresse 6 January 1995)

We estimate that the spent fuel production of the Dodewaard plant, from the beginning of its operation to its definitive shut down in March 1997, to be 57 MT[19].

We had initially estimated that the quantity of spent fuel which has been produced by the Dodewaard plant would be smaller than the quantity of spent fuel which has been contracted to be reprocessed (57 MT to be produced as compared to 61 MT under contracts of which 8 MT already reprocesseed). However because the quantity of spent fuel which is discharged each year is about 2 MT, it can be supposed that the core of the reactor contains about 6 MT fuel (on the basis of a third-of-the-core refuelling mode), and that the spent fuel production is about 4 MT higher than our initial estimate, which would correspond to a lower average burnup rate (23,000 MW.d/MT). Whatever the exact figure, **the quantity of spent fuel produced by the Dodewaard plant is about the quantity under reprocessing contracts. This means that according to current engagements, all the spent fuel from this plant would be reprocessed.**

The Future of Reprocessing in Europe

Two foreign customers ("baseload customers") of the UP3 plant have left a part of their share of the reprocessing contracts to be taken by German and Japanese utilities.

The Swedish utility which had a reprocessing contract for the reprocessing of 672 MT spent fuel (which later increased to 784 MT) has passed these contracts to German and Japanese utilities. Remaining formally a reprocessing customer of COGEMA, Sweden has "swapped" (exchanged) spent MOX fuel from Germany to be stored with other spent fuel in Sweden, for the spent fuel it had already sent to La Hague for reprocessing. This was done at the end of the 1980s, and enabled the Swedish utilities to be reimbursed, via other utilities, of the sums it had already prepaid to COGEMA.

Switzerland also reduced by 0.5% its share of the UP3 reprocessing contracts, which corresponds to 37 MT spent fuel, but no information is available on a possible similar swap with other spent fuel from other countries. Supposedly, the corresponding Swiss spent fuel had not yet been sent to La Hague and will be managed with the other spent fuel in Switzerland for which no reprocessing is planned.

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[19] As of 31 December 1996, the Dodewaard plant had produced 11.3 TWh. The electricity generation for both 1995 and 1996 was each 0.42 TWh. Thus we have estimated the electricity generation of the plant until its definitive shutdown at the end of March 1997 to 11.4 TWh. It can be noted that the Dutch government has published the following figures on spent fuel production from the Dodewaard plant: the spent fuel production of the Dodewaard plant would be "about 2 MT" per year, and this spent fuel would contain 13 kg plutonium (8.8 kg fissile plutonium) [Tw.Kamer91]. The Dodewaard plant has generated 0.38 TWh in 1989 and 0.43 TWh in 1990. Taking the average electricity generation during these two years, the figure of "about 2 MT" corresponds to a burn-up rate of about 25,000 MW.d/MT. We have used this figure to determine the total spent fuel production of the Dodewaard plant. On the basis of this hypothesis, **our calculation gives 57 MT for total spent fuel production.**

Furthermore, according to a confidential COGEMA document, the planned throughputs of reprocessing after year 2000 will be reduced to 1,300 MT per year, even taking into account post-2000 contracts. The throughput could be further reduced if EDF does not engage itself as much in other reprocessing contracts as it has planned. It should be noted that EDF has not signed any post-2000 contract as of the middle of may 1997.

However, it seems that the overall cost of the plutonium industry for the French domestic utility EDF, the utility with the largest reprocessing engagements, would be an increase of the cost of electricity generation by FF 0.04-0.05 per kWh[20]. This very high figure corresponds to 20-25% of the total cost of electricity production. Because of the future opening of the European electricity market, all utilities are trying to cut costs and the non-reprocessing option seems like a plausible cost saving measure.

1.3. Plutonium from the Dismantling of Warheads

The collapse of the Soviet Union has put an end to the Cold War and to the increasing race for nuclear weapons. In the framework of the dismantling of part of the nuclear weapons arsenals in the US and in the Russian Federation, about 50 MT of Russian and 50 MT of US weapons grade plutonium will have to be disposed of. According to the results of an intergovernmental meeting in Paris in October 1996, two solutions have been proposed: the transformation of the plutonium into oxide and the fabrication of MOX fuel for use in LWRs, and the vitrification of the plutonium together with high-level radioactive waste. As of October 1996, no solution was preferred even though the French representative noted that the first solution would degrade the plutonium and the second solution would not take advantage of the energetical content of plutonium[21]. The French represen-tative was of course promoting the solution which would be most favorable to the French nuclear industry, enabling participation in new facilities for the French plutonium industry. A US Department of Energy Record of Decision (ROD) dated 14 January 1997 confirms the US Government interest in both solutions for the management of the plutonium.

Two companies are also particularly interested in the MOX solution. Both the Belgian Belgonucléaire and the German Siemens have much invested in two MOX plants which should have been operated in Belgium and in Germany. Since the license of these plants was never granted - the Belgian plant was never built while the German plant was almost complete - these two companies are eager to be able to sell at least parts of their condemned facilities or of their design to recuperate some of the investment they made. Belgonucléaire has already started redesigning the abandoned P1 MOX plant in order for it to be able to handle military plutonium. It is however highly unlikely that any plutonium from the US or Russia would ever be imported to Belgium for this purpose. But

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[20] *Libération,* 9 avril 1997.

[21] Press Conference after the G7, Russia, Belgium, Switzerland and IAEA meeting in Paris on 31 October 1996 by Mr. Cl. Mandil, Director for Energy at the Ministry of Industry, France.

Belgonucléaire might also offer the technology for application in the US or Russia.

The presence of the "surplus" weapons grade plutonium has important implications for the plutonium industry. On the one hand it might open a new market for MOX fuel fabrication, on the other hand it **increases the international plutonium inventory significantly.**

All countries which are using or planing to use MOX fuel in their reactors (Belgium, France, Germany, Japan, the United Kingdom and Switzerland) already have each a large plutonium stockpile from the reprocessing of their spent fuel. The weapons plutonium stockpiles disables any economic interest for these countries to purchase plutonium from another country, for instance from the Netherlands.

2. LIABILITIES OF THE PLUTONIUM INDUSTRY

The objective of this report is to present quantitative elements of the inventory and management of Dutch plutonium in order to have a qualitative debate on future options. The following short chapter however gives brief qualitative elements on the consequences of plutonium management in the nuclear industry.

Plutonium does not exist naturally, apart from the very limited quantities which are present in uranium ore and that which are left from the beginning of the universe[22]. Plutonium was discovered in 1940 by Glen T. Seaborg in December 1940 and first produced in larger quantities for the American nuclear weapons programme. The bomb which exploded over Nagasaki on 9 August 1945 contained plutonium.

Both plutonium-239 and -241 isotopes are fissile, which means that the combined concentration of a certain amount of these radionuclides forms a critical mass and initiates a nuclear explosion (a bare metal sphere of about 10 kg of plutonium-239). These isotopes are also used, as well as uranium-235 which is the fissile isotope of uranium, to produce electricity in a nuclear reactor.

2.1. Liabilities due to the Characteristics of Plutonium

Plutonium in the civil industry is mostly present in the form of oxide (PuO_2) powder, while the military convert it to metal.

[22] There are trace quantities of plutonium-239 in uranium ore due to reaction with uranium-238 and traces of plutonium-244 naturally due to the very long half-life of this radionuclide (more than 80 million years).

Radiological Protection

The first isotope to be produced during the fission of uranium in a nuclear reactor is plutonium-239, the isotope which is most wanted for military uses. The longer nuclear fuel is used in a reactor, the more plutonium is produced in the nucleal fuel, and the more there is of other isotopes than plutonium-239 in the produced plutonium.

The following table gives general radioactive characteristics of the plutonium isotopes in plutonium from reprocessed spent fuel. The table also gives the corresponding characteristics for americium-241. Americium-241 builds up from the decay of plutonium-241 which has a relatively short radioactive half-life.

Table 4: Radioactive half-life and type of decay of plutonium isotopes and of americium-241

Isotope	Radioactive half-life (yrs)	Principal decay mode
Plutonium-238	87.74	α
Plutonium-239	24,110	α
Plutonium-240	6,537	α
Plutonium-241	14.4	β
Plutonium-242	376,000	α
Americium-241	433	α

(Source: F.Barnaby, pers. com.97,Pescayre84)

Plutonium-241 is the only β emmiter. A β particle is shielded by a few millimeters of aluminium. However, this particle can travel a few meters in the air and requires additional shielding than for only α emitters. An α particle is larger and creates more detriment than a β particle. However, because of its size, it is shielded by anything as thin as a sheet of paper.

The presence of plutonium-241 has two consequences. It requires further shielding to cope with the β activity. Also, because of plutonium-241 disintegration, the total plutonium becomes less pure with the buildup of americium-241, a powerful gamma emitter. This has consequences on the possible uses of plutonium in MOX fuel for LWRs.

The following table gives inhalation and ingestion doses for the incorporation of plutonium, according to the European directive on radiological protection (June 1996), on the basis of a typical plutonium isotopic composition from 33,000 MWday/MT spent fuel from a standard LWR.

Table 5: Dose engaged from inhalation or ingestion of plutonium oxide from LWR spent fuel [23]
(for comparison: lethal dose: about 10-20 Sv
max. dose allowed for the public: 0.001 Sv/year)

Type of incorporation and of population	Dose engaged (Sv/µg)
Ingestion dose for population AGE<1	0.084
Ingestion dose for population AGE>17	0.0055
Ingestion dose for workers	0.0011
Inhalation dose for population AGE<1	4.239
Inhalation dose for population AGE>17	0.315
Inhalation dose for workers (Pu oxide 1 µm)	0.296
Inhalation dose for workers (Pu oxide 5 µm)	0.195

(WISE-Paris calculation from 1996 Euratom Directive)

The most important health consequences are those arising from the inhalation of small particles of plutonium. Inhalation doses are more than fifty times greater than ingestion doses for the ingestion of the same quantity. The table shows that **the inhalation of a quantity of the order of tens of microgrammes (µg) is lethal, in particular for small children**. Safety measures must ensure that during an accident in a facility or during transportation, no plutonium is released into the environment.

In addition it should be stressed that these figures are mainly based on estimates derived from animal experiments and therefore only of limited reliability.

Plutonium is also toxic chemically. However, the chemical effects of plutonium are negligible as compared to its radiological effects.

Proliferation Concerns

The nuclear industry often tries to minimise the possibility of producing a nuclear weapon with plutonium from standard LWR spent fuel. For instance, according to COGEMA, "to produce a nuclear weapon with plutonium, it is required very pure plutonium which contains a high percentage of fissile isotopes"[24]. Plutonium from standard LWR spent fuel contains 70-80% of the plutonium-239 and plutonium-241 fissile isotopes, while plutonium used by the military contains 90-95% plutonium-239. However, the International Atomic Energy Agency (IAEA), which supervises the non-proliferation safeguards regime worldwide, is much more precise. According to its Director General, Mr. Hans Blix, IAEA "considers high burn-up 'reactor grade' plutonium and in general **plutonium of any isotopic composition with the exception of plutonium containing more than 80% plutonium-238 to be capable of use in a nuclear**

[23] The isotopic composition which is used here is the following: plutonium-238 (1.9%), plutonium-239 (59.5%), plutonium-240 (24.5%), plutonium-241 (10.2%), plutonium-242 (4.0%).
[24] *"Non-prolifération : le point de vue de l'industriel"*, COGEMA Press Conference, 14 April 1994.

explosive device. There is no debate on this matter in the Agency's Department of Safeguards"[25].

Standard spent fuel contains only a few percents of plutonium-238. Any plutonium from LWR spent fuel, of which the **plutonium separated from Dutch spent fuel from the Borssele and Dodewaard plants, can be used to produce a nuclear weapon**.

The plutonium which is recuperated from FBR spent fuel, in particular the so-called blanket elements for instance **from Superphénix**, contains an even higher percentage of plutonium-239 than the plutonium which was introduced in Superphénix. In fact, the blanket plutonium is about 97% plutonium-239 and therefore of excellent weapons quality.

2.2. Liabilities due to the Use of Plutonium in the Nuclear Industry

Americium-241 Content in Plutonium for MOX

Americium-241 buildup in plutonium, due to the disintegration of plutonium-241, modifies the neutronic proporities of the plutonium and of the MOX fuel which is produced with it. In particular, a limit for the americium-241 content of plutonium is imposed on plutonium which is used to produce MOX fuel.

The best way to limit the americium-241 content is to use the plutonium as soon as possible after reprocessing, since the plutonium produced in reprocessing plants is "clean". The longer the plutonium is stored after reprocessing, the more it becomes contaminated with americium-241.

Technically, americium-241 can be separated from plutonium, but in the process new wastes are produced. A facility for separating americium, called the plutonium redissolving unit (URP) went into operation in 1994 at the La Hague plant. Separating americium is an expensive operation and the estimated cost of the purification of plutonium is estimated to be around US $ 10 to 28 per gramme (HFL 19-54 per gramme) [NEA89].

Criticality in MOX Plants

Because of the fissile properties of the plutonium, special measures have to be respected wherever plutonium is manipulated in order to avoid the concentration of a critical quantity of plutonium which would initiate an uncontrolled nuclear chain reaction and potentially a subsequent explosion. Stringent limits exist for the quantities of plutonium inside a process or in a container, in reprocessing plants, in plutonium stores, for plutonium transportation and in MOX fabrication plants.

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[25] Letter from Mr. Hans Blix, Director General of IAEA, to Mr. Paul Levanthal, Director of Nuclear Control Institute, 1 November 1990.

Particular precautions have to be taken to avoid the presence of other materials which could enhance criticality. Water is a moderator of nuclear reaction and the plutonium must be kept dry in the facilities. For instance, the design of the P1 MOX plant from Belgonucléaire has taken into account the possibility of a flood for the matter [Debauche97].

Safeguards in the Nuclear Industry

Special physical protection measures and safeguards (accountability of nuclear materials) are necessary in the nuclear industry to avoid or to be able to detect diversion of plutonium and other nuclear materials which could be used for military purposes. Physical protection and safeguards are not equally stringent in different countries.

For instance, the Melox plant is licensed to produce 100 tonnes MOX fuel per year and is licensed to store 14 tonnes of plutonium. The Siemens plant which was never operated at Hanau was designed to produce 120 tonnes MOX fuel per year. However, this larger plant was at the time only licensed to handle 2.5 tonnes of plutonium in the facility.

Also international safeguards are meant to verify that countries which have not produced any nuclear weapons, and which have pledged not to do so in the framework of the nuclear non-proliferation treaty, are not diverting any material from their official civil use. However, both remaining countries to have a reprocessing industry, United-Kingdom and France, are nuclear weapons states. These states are subject to a particular international safeguards regime which enables them to continue to have a nuclear weapons capability and specifically allows to swap nuclear materials between their civil and their military inventories and to operate so called "mixed facilities" sometimes on a civil or on a military mode.

In Europe, Safeguards are organised by the Euratom in agreement with the International Atomic Energy Agency (IAEA). In France and in the United-Kingdom, the two European nuclear weapons states, the Euratom Safeguards must comply with national sovereignity requirements. Particularly, in France, because the civil and military nuclear industries have been developed together, **it is not possible to guarantee that some foreign plutonium, of which Dutch plutonium, has not entered the French military programme**[26].

[26] For details see Mathieu Pavageau, Mycle Schneider, "Dutch Plutonium and the French Nuclear Weapons Programme", WISE-Paris, commissioned by Greenpeace Netherlands, January 1996.

3. THE SITUATION OF PLUTONIUM MANAGEMENT IN DIFFERENT COUNTRIES

3.1. Plutonium Management in Spain and in Italy

There are two countries which are in a somewhat similar situation concerning the management of plutonium as that of the Netherlands: Spain and Italy have accumulated a stockpile of separated plutonium but no use can be envisaged for this material in the respective country.

Spanish Plutonium

Spent fuel from the José Cabrera and the Santa Maria plants was sent until 1983 for reprocessing at the BNFL plant at Windscale, United Kingdom. **Spain had the option to recuperate the plutonium from the reprocessing of this spent fuel, but has renounced to this option[27].**

Spanish utilities further have reprocessing contracts with the British BNFL for the reprocessing of 145 MT of spent fuel at the THORP plant. This reprocessed spent fuel will produce about 1.5 MT of separated plutonium. We have not found any information on whether or not Spain has already decided to renounce to this plutonium or not.

The spent fuel from the Vandellos-1 magnox plant was reprocessed in France according to a different agreement. The French utility EDF owned a share of 25% of the Spanish operator of the plant. Together with the supply of the French designed plant, France agreed to supply the fresh fuel for this plant and take back and manage the spent fuel.

The Vandellos plant was definitely shut down in 1990. All the spent fuel elements, except for two, were sent to France for reprocessing[28]. We estimate that the 55.6 TWh electricity generated has produced about 2.1 MT plutonium.

We therefore estimate Spain's cumulated separate plutonium inventory to be from 2.1 to 3.6 MT plutonium. There are still nine nuclear power plants operated in Spain. However, it is not planned that they be fuelled with MOX. Consequently, Spain will have to try to sell this plutonium, to give it away, to pay another country to keep it, to store it in Spain or to find another solution for its final destination.

Italian Plutonium

A 1987 referendum in Italy put an end to nuclear power. The three reactors which were operated at the time were definitely shut down in 1987 and 1988. However, this referendum did not require Italy's disengagement from the

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[27] "Envio de Combustible Irradiado de España al Reino Unido", Consejo de Seguridad Nuclear, 31 May 1993.

[28] Letter from the Consejo de Seguridad Nuclear to Greenpeace-Spain, 29 February 1996.

European FBR programme. Italy owns 33% of NERSA and is thus the largest foreign investor in the Superphénix FBR in France.

In the framework of this collaboration, Italy was entitled to supply 33% of the plutonium which was necessary for the fabrication of the nuclear cores for this reactor. The total quantity of plutonium Italy was supposed to supply was about 3,900 kg[29]. Italy has therefore purchased plutonium from other European countries, and in particular 328 kg from the Netherlands.

No information has been found on the planned management of the plutonium once it is recuperated from the FBR programmes. The quantity of plutonium which will be attributed to Italy from the first core of the Superphénix reactor will be greater than what Italy has supplied, since the reactor has been operated in a breeder configuration.

Italy therefore will have to manage a quantity of roughly 4,000 kg of plutonium. No easy solution will be found for this quantity since there is no reactor operated and it is not possible to use this material in Italy. Also it should be stressed that - as outlined above - a certain amount of the Superphénix plutonium will be of weapons grade. Nothing has been officially decided on the destination of this plutonium.

3.2. Management of Plutonium with MOX Fuel: an Increasing Stockpile of Separated Plutonium

This chapter briefly describes the trends in the plutonium industry in Europe. Belgium, France, Germany, Switzerland, and the United-Kingdom are starting to use MOX fuel in light-water reactors, and have officially as an objective, the consumption of the quantities of separated plutonium which has been and will be produced in the reprocessing plants. The situation is quite similar with Japan, which is a reprocessing customer of both the United-Kingdom and of France.

At the moment, and for a long time to come, the flows of different nuclear materials in the nuclear industry are not matching. In particular the quantities of plutonium separated in reprocessing plants are larger than the quantities which can be absorbed by operating MOX fabrication plants. The number of reactors which could use MOX fuel is larger than the number which could be supplied by the MOX fabrication plants. In other words, the lack of MOX fabrication capacity increases the inventories of separated plutonium. However, it should be noted that certain operators, e.g. in Germany, are not using the MOX option although they have the corresponding licences and plutonium available.

[29] ENEL was entitled to supply 33% of the two first cores for the Superphénix reactor (each containing about 5,900 kg plutonium).

The following table gives the names of the reactors which were using MOX fuel at the beginning of 1997.

Table 6 Reactors using MOX fuel, as of beginning of 1997

Country	Reactor
France	Saint-Laurent-1, Saint-Laurent-2, Gravelines-3, Gravelines-4, Dampierre-1, Dampierre-2, Le-Blayais-2, Tricastin-2, Tricastin-3, Tricastin-1
Belgium	Tihange-2, Doel-3
Germany	Obrigheim, Neckarwestheim, Unterweser, Grafenrheinfeld, Philippsburg, Grohnde, Brokdorf
Switzerland	Beznau-1, Beznau-2

(Source: Lebastard97, Duckwitz97...)

Belgian Plutonium

The Belgian Synatom which manages the spent fuel from the seven operated reactors has signed reprocessing contracts with the French COGEMA. Similarly as SEP, Synatom has signed contracts for the reprocessing in UP2 and has a share in the UP3 baseload contracts. However, Synatom was obliged by the Belgian Parliament in 1993 to freeze its previous engagements for post-2000 contracts. Synatom had at the time also been required to try to resell or subcontract previous reprocessing contracts to other of COGEMA's customers. Synatom answered that other customers "had shown no interest".

There is however yet another reprocessing contract under discussion. It concerns spent highly-enriched uranium (HEU) fuel from the BR-2 research reactor at Dessel, operated by SCK/CEN. We have not found any information on the quantity of spent fuel this represents, even though the discharged quantity is much less than for commercial reactors. As of February 1997, the COGEMA offer for reprocessing at La Hague had been retained, though no contract had been signed yet.[30]

The **production of MOX** started very early in Belgium, and Belgonucléaire has produced a large share of the MOX fuel in the world up to the 1990s. A pilot plant was operated in the 1960s, and produced the first MOX fuel which was used in 1963. A 35 MT commercial MOX fabrication plant (the P0 plant) was commissioned in 1972, and has produced MOX for both BWRs (Boiling Water Reactors) and PWRs (Pressurized Water Reactors). Clients comprise utilities in Belgium, France, Germany and Switzerland. A recent agreement will allow for the production of MOX fuel for Japanese BWRs with plutonium from the reprocessing of Japanese spent fuel at La Hague. As of the beginning of 1997, this plant had produced 315 tonnes of fuel, more than half of the total cumulated world production of 600 tonnes.

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[30] *NuclearFuel*, 10 February 1997.

The P0 plant has produced 36 MT MOX fuel in 1996 [Lebastard97] and we consider that the annual throughput will be 35 MT until year 2000.

Another MOX plant has been planned in Belgium but was never built and operated, because its construction license which was granted in April 1991 was cancelled by the Supreme Court in 1996. Today, Belgonucléaire is trying to sell its plant to any potential buyer, as Siemens is doing with the abandoned MOX plant at Hanau. Belgonucléaire is even redesigning the P1 plant "to respond to particular needs of the weapons plutonium transformation into MOX" [Debauche97].

British Plutonium

The British BNFL has operated since 1994 a reprocessing plant called THORP, the customers of which are mostly foreign. The planned throughputs for years 1996 and 1997 are respectively 430 and 670 MT. From 1998 onwards, BNFL plans to reach 900 MT annual nomical capacity[31].

The MOX production experience in the United-Kingdom is quite low, even though it started very early for research and demonstration purposes. The first plant to be operated is the MOX demonstration facility. Three tonnes of experimental MOX fuel for LWRs were produced there in the 1960s, and fifteen tonnes of MOX for FBRs were produced from 1970 to 1988. This plant has been adapted for the fabrication of LWR-MOX, called MDF (MOX Demonstration Facility) and produces about 8 MT of MOX per year for the Beznau plant in Switzerland.

A full scale plant, the Sellafield MOX plant (SMP), with a nominal throughput of 120 MT is in start up. About ten tonnes MOX fuel for LWRs were produced there. This makes a total for the UK of more than 28 tonnes of MOX fuel, of which half was for FBRs [Martin97].

German Plutonium

In Germany, Siemens operated a demonstration MOX fabrication plant at Hanau until 1992. The operation of the 35 tonnes nominal throughput plant was ended after the contamination of three workers and long standing political opposition to the facility by the SPD/GRÜNEN coalition govern-ment. From 1968 to 1991, the plant produced about 135 tonnes of MOX fuel, 90% of which was for LWRs[32].

Siemens built another larger MOX plant on the same site, the planned annual throughput was 120 MT. In 1993, at a time when the plant was 95% complete and about $ 800 million had been spent, the Land of Hesse blocked the licensing of the plant and the plant was never operated. In order to fulfill MOX supply contracts it had with utilities, Siemens has agreed with the French CEA and COGEMA to have MOX fuel produced at the MOX fabrication plant at Cadarache, complying with Siemens MOX specifications. Mr. Jürgen Krellman,

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[31] BNFL News, Risley/Capenhurst edition, No. 263, May 1996.

[32] Krellman, J., "Plutonium Processing at the Siemens Hanau Fuel Fabrication Plant", Nuclear Technology, April 1993.

former director of the MOX plant at Hanau, was appointed Director at the Cadarache plant[33].

The German consortium also counts to stay within the competition on the MOX market on the basis of plutonium from warhead dismantling. "Siemens is in a position to offer qualified services, resources, technologies and experience for the consumption of weapons-grade plutonium in LWRs" [Duckwitz97].

French Plutonium

In France, the CEA has operated a MOX fabrication plant at Cadarache, which has produced MOX fuel for both FBRs and LWRs. Today, with the appointment of a German director, the plant is entirely devoted to the production of MOX fuel for LWRs, and in particular for German utilities. The Cadarache plant was qualified for MOX fuel for German PWRs for first delivery early 1997.

Because it is becoming increasingly obvious that less European utilities are to have their spent fuel reprocessed, COGEMA is now "very interested" in potential markets for reprocessing in Asia, for instance approaching South Korean or Taiwanese utilities[34]. The US have always opposed the spread of reprocessing of spent fuel for non-proliferation matters. It is unlikely that COGEMA's commercial efforts in this direction will have any success.

Another plant has been operated by COGEMA in France since 1994, the MELOX plant with an annual capacity of 100 MT. COGEMA wants to increase the capacity of the plant but additional capacity will not be available before year 2000.

The MELOX plant at Marcoule has produced 50 MT of MOX fuel during 1996, and the Cadarache CFCa plant has produced 23 MT MOX [Lebastard97]. We estimate that these two plants will reach nominal capacity from 1997 onwards, that is 35 MT for the Cadarache Plant and 100 MT for the MELOX plant.

Stockpile of Separated Plutonium

From the data which have been given above, we have estimated the variation of the stockpile of plutonium in Europe.

The following table gives the production of plutonium from the reprocessing plants in France (La Hague) and in the United-Kingdom (THORP). The basis of the estimate is a 1% content of plutonium in spent fuel.

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[33] *NuclearFuel*, 5 July 1993.

[34] *NuclearFuel*, 7 April 1997.

Table 7: Estimate of quantities of spent fuel reprocessed at La Hague and separated plutonium production (1996-1999)

Year	Quantity reprocessed at La Hague (MT)	Quantity reprocessed at THORP (MT)	Total Quantity reprocessed La Hague+THORP (MT)	Total production of plutonium (MT)
1996	1,681	430	2,111	**21.1**
1997	1,600	670	2,270	**22.7**
1998	1,600	900	2,500	**25.0**
1999	1,600	900	2,500	**25.0**
Total plutonium production 1996-1999				**93.8**

The following table gives the estimated consumption of plutonium, through the fabrication of MOX in the existing MOX plants. The basis of the estimate is 7.5% plutonium in MOX fuel.

Table 8: Estimate of quantities of MOX fuel produced and separated plutonium consumed (1996-1999)

Year	Production of the MOX Fabrication Plants (MT)						TOTAL consumption of plutonium (MT)
	Dessel P0	Cadarache CFCa	Mélox	Sellafield MDF	Sellafield SMP	TOTAL	
1996	36	23	50	8	0	**117**	**8.8**
1997	35	35	100	8	0	**178**	**13.4**
1998	35	35	100	8	60	**238**	**17.9**
1999	35	35	100	8	120	**298**	**22.4**
Total plutonium consumption 1996-1999							**62.5**

From the above figures on the production and consumption of plutonium, we have estimated the variation of the separated plutonium inventory. The basis of the calculation is a conservative estimate of 88.1 MT of separated plutonium stockpile in Europe, as of 1 January 1996. This is based on a 2.5 MT inventory in Germany (Cf. below), a 44 MT inventory in the United-Kingdom[35] and a 41.6 MT inventory in France[36].

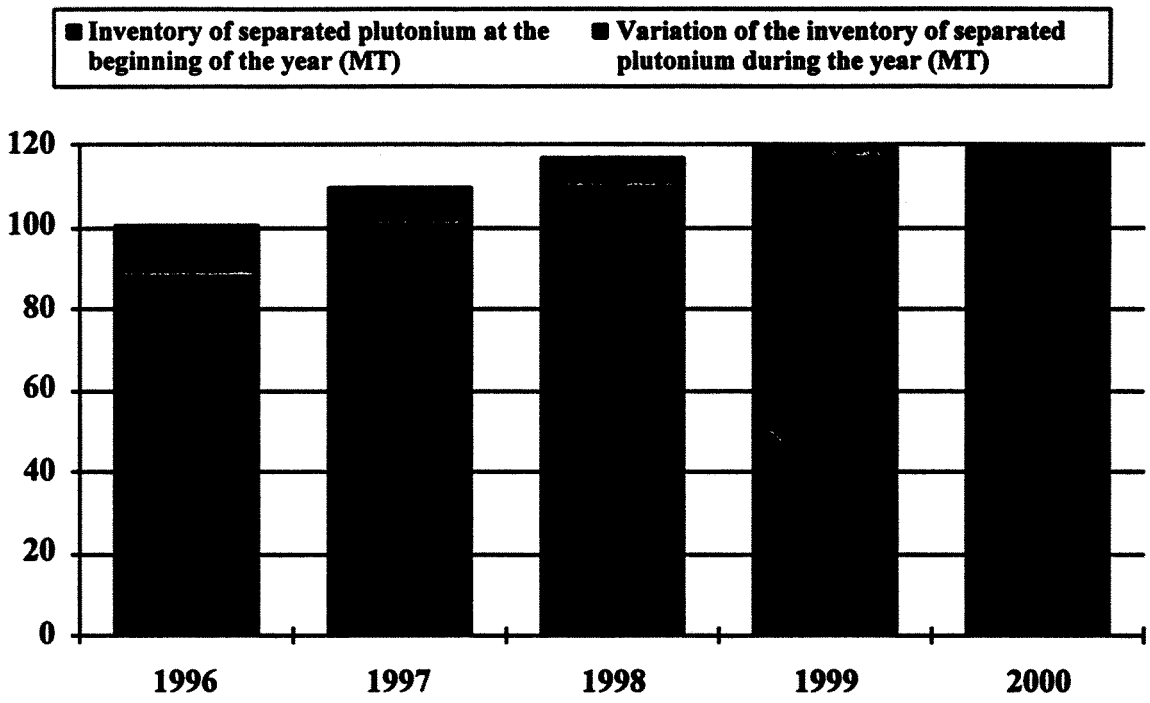
[35] Inventory as of 31 March 1995 as published by the United-Kingdom Department for Enterprise on 13 July 1995. The inventory of plutonium as of 1 January 1996 is larger than this figure.

[36] Figures published by the Industry Ministry in the booklet "L'énergie nucléaire en 110 questions", dated October 1996.

Table 9: **Estimate of quantities of separated plutonium produced and consumed, and inventory of separated plutonium (1996-1999)**

End of year	Quantity of separated plutonium produced at La Hague during the year (MT)	Quantity of separated plutonium consumed in the MOX plants during the year (MT)	Variation of the inventory of separated plutonium (MT)	Inventory of separated plutonium at the end of the year (MT)
1995				88.1
1996	21.1	-8.8	+12.3	100.4
1997	22.7	-13.4	+9.3	109.7
1998	25.0	17.9	+7.1	116.8
1999	25.0	22.4	+2.6	119.4

Chart 9: **Estimate of quantities of separated plutonium produced and consumed, and inventory of separated plutonium (1996-2000)**



We estimate the stockpile of separated plutonium in Europe as of 1 January 2000 to be about 120 MT.

Taking into account the feasible evolution of the plutonium industry[37], we make the following assumption for the evolution of the separated plutonium stockpile in Europe: As of 1 January 2005, no less than 100 MT, and as of 1 January 2010, no less than 80 MT. This estimate of course does not take into account any civil management of weapons grade plutonium in Europe, either from the UK or from France, or from Russia, China or the USA.

[37] The COGEMA MOX plant at Cadarache is due to be shut down, while COGEMA has stated that it wants to double the production at its Melox plant at Marcoule.

4. MANAGEMENT OF DUTCH PLUTONIUM

This chapter first gives quantitative information on the inventory of Dutch plutonium, and then discusses the management options of this inventory.

4.1. Dutch Plutonium Inventory

The elements which are necessary to make an estimate of the inventory of Dutch plutonium are the following:

- quantities of Dutch spent fuel which have been reprocessed and which are planned to be reprocessed (Cf. above);
- quantities of separated plutonium which have been transferred and sold to foreign countries, in particular that which was supposed to be used in the Superphénix and Kalkar FBRs.

The following table gives again the information relevant to the quantitites of spent fuel to be reprocessed and their burn-up rates. The two columns on the right give the corresponding estimated plutonium content (on the basis of a linear variation of plutonium content), together with the plutonium content of the spent fuel to be reprocessed.

Table 10: Plutonium Content in Spent Fuel from the Borssele and Dodewaard Power Plants

Reprocessing contracts and corresponding quantities	Estimated burnup rate (MW.d/MT)	Estimated plutonium content in spent fuel (kg/MT)	Plutonium content in spent fuel (kg)
Borssele: 85 MT, La Hague UP2 *already reprocessed*	33,000	10.0	850
Borssele: 140 MT, La Hague UP3 *77MT reproc. as of 1 March1997*	33,000	10.0	1,400
Borssele: 156, La Hague Post-2000 *not yet reprocessed*	35,000	10.6	1,650
Dodewaard: 8 MT, Eurochemic *already reprocessed*		5.9	47
Dodewaard: 53 MT, THORP *not yet reprocessed*	25,000	7.0	370
TOTAL			**4,320**

(Sources: COGEMA94, Tw.Kamer91, Wolff96, Enerpresse 6 January 1995...)

It can also be mentioned, though no precision can be given on the quantities, that spent fuel from two research reactors in the Netherlands, the HFR

reactor operated by Euratom and the Athene reactor, had some of their spent fuel reprocessed at the Eurochemic plant [Wolff96].

The following table gives the quantity of Dutch plutonium which was produced through the reprocessing of Borssele and Dodewaard spent fuel at the La Hague and Eurochemic plants, together with quantities of transfers of Dutch plutonium which have already occured. The last line of this table gives as result the inventory of Dutch plutonium which has been produced through reprocessing and which has not been used. This is the Dutch separate plutonium stockpile.

Table 11: Status of Dutch Plutonium from Spent Fuel Which Has Been Reprocessed, *and Dutch Separate Plutonium Stockpile* (kg)

Status	From the Borssele Plant	From the Dodewaard Plant	TOTAL
Separated plutonium, as of 1 March 1997	**1,620**	**47**	**1,667**
Sale to SBK for Kalkar (1979)	*-174*		*-174*
Sale to COGEMA for Superphénix (1980)	*-68*		*-68*
Sale to ENEL for Superphénix (1981-83)	*-328*		*-328*
Sale to SBK/NERSA for Superphénix (1985)	*-47*		*-47*
Sold for testing to Belgonucléaire (1972)		*-4*	*-4*
Sale to SBK for Superphénix (1984)		*-43*	*-43*
TOTAL *Dutch Separate Plutonium Stockpile*	**1,003**	**0**	**1,003**

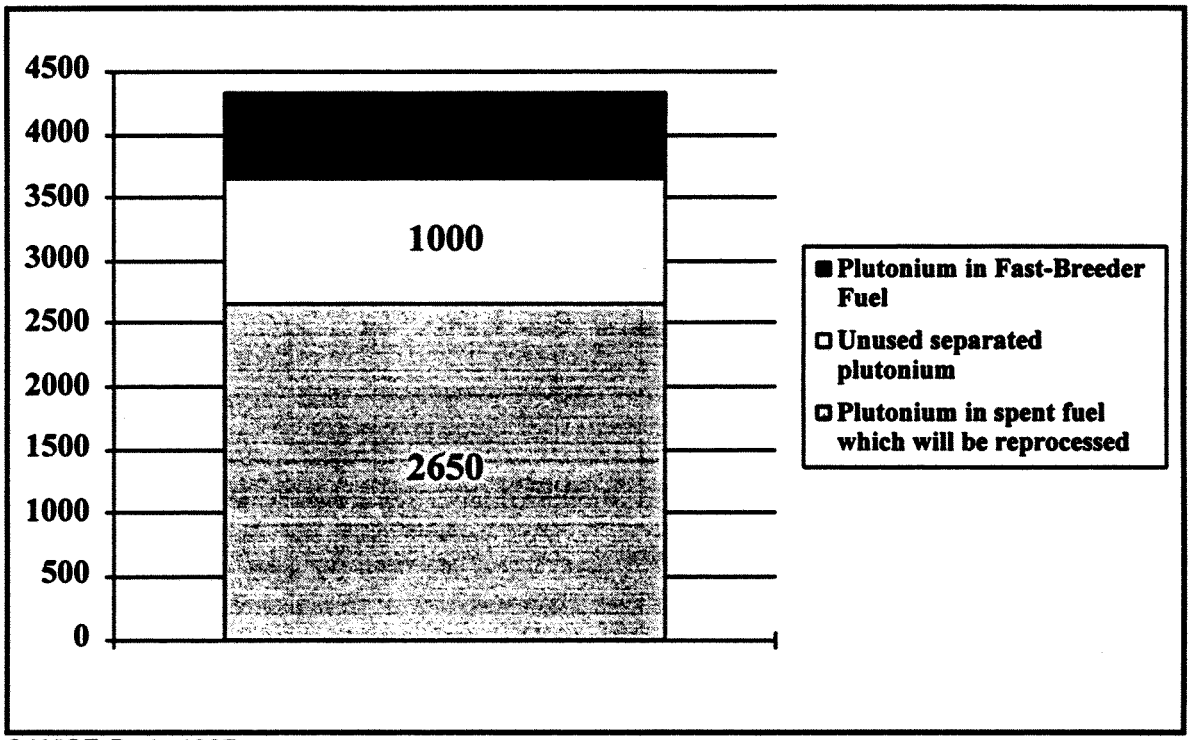
(Sources: Tweede Kamer, Lijst van Antwoorden, 5 November 1985 and Tw.Kamer91)

The following table gives an estimate of the Dutch plutonium total inventory, taking into account plutonium which has not yet been separated through reprocessing, plutonium which has been separated and which has not been used, and plutonium which has been separated and which has been used in the FBR programmes.

Table 12: Estimate of Dutch Plutonium Production, according to current engagements (kg)

Plutonium Form	From the Borssele Plant (Hypothesis: 381 MT spent fuel discharged until 2004)	From the Dodewaard Plant (Hypothesis: 68 MT spent fuel discharged until 31 March 1997)	TOTAL
Plutonium in spent fuel planned to be reprocessed *taking into account the spent fuel to be produced from the Borssele plant until 2004*	2,280	370	**2,650**
Unused separated plutonium, *as of 1 March 1997*	1,000	0	**1,000**
Plutonium in Fast-Breeder Fuel	620	50	**670**
TOTAL	**3,900**	**420**	**4,320**

Chart 12: Estimate of Dutch Plutonium Production, according to current engagements (kg)



This table and the corresponding chart show that out of the 1,670 kg separated plutonium which have been produced from the reprocessing of

Borssele and Dodewaard spent fuel, only 670 kg have been used. The other 1,000 kg are stored at La Hague, at the cost of SEP.

Furthermore, taking into account the spent fuel which is yet to be produced by the Borssele reactor until its planned shut down in 2004, there will be 2,650 kg plutonium inside spent fuel at that date, the total quantity of which is planned to be reprocessed and converted into separate plutonium, even though no use for this plutonium has yet been found.

4.2. Any Solution for Dutch Plutonium?

Dutch plutonium today is in the form of different nuclear materials: non reprocessed spent fuel awaiting reprocessing, separated plutonium stored at the La Hague reprocessing plant, and incorporated into FBR fuel. It is planned that the part of the Kalkar fuel which was sent to Dounreay in the UK be reprocessed. Similarly, it is planned that the Superphénix fuel be reprocessed (current planning is that the fuel be reprocessed at La Hague). The plutonium which is inside the FBR fuel will thus be separated. Therefore under current planning, all Dutch plutonium is due to be separated from spent fuel.

The planned objective according to the Dutch government for this separated plutonium, since no domestic use can be identified, is to sell or transfer it so other utilities would be able to make MOX fuel from it[38]. This sale or transfer should be made according to better technical and financial conditions than if the fuel had not been reprocessed (i.e. making a comparison between the conditions for the management of the spent fuel in the Netherlands and the conditions for the management of the reprocessing wastes in Netherlands and of the plutonium wherever and however it is managed)[39].

It can easily be doubted that this could be the case, and this for many reasons:

• All of the few countries which could use this plutonium already have a significant surplus of separated plutonium and will surely not be willing to pay much or anything to increase this surplus. We have shown that there will be a gigantic surplus of at least 120 MT of separated plutonium in Europe at the beginning of year 2000. Since the use of MOX fuel is not economic, the utilities which planned to develop the use of MOX fuel will tend to reduce both reprocessing and the use of MOX fuel.

• The volume of radioactive waste from reprocessing is significantly larger than the volume of the original spent fuel and the comparison between the management of the reprocessing wastes and of the spent nuclear fuel is favorable to the direct disposal of spent fuel.[40] In any case, no decision

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[38] Electricity Utility and Ministry for Economic Affairs, Tweede Kamerstukken II, 1996-1997, 25 422, no. 1.

[39] Opwerking van Nederlandse Splijstof, Een Analyse, ECN-C-97-031, ch. 7, Mei 1997.

[40] Cf. in particular Frank Homberg, et al., "COGEMA-La Hague, the Waste Production Techniques", WISE-Paris, December 1994, updated may 1997

concerning the management of the Dutch highly radioactive waste has yet been made;

If no other utility is interested in the Dutch plutonium, this would merely be the ultimate demonstration of an erroneous spent fuel management strategy. Apart from the high cost of having produced a useless dangerous material, the storage of the plutonium will be very costly and might lead to politically difficult situations.

The German Plutonium Problem

The German situation is quite comparable to the Dutch situation when it comes to the problem of surplus plutonium management. Germany has a 2,400 kg plutonium stockpile (1,800 kg fissile plutonium) at the plutonium bunker at the Siemens site in Hanau. Besides the Hanau plutonium there is a much larger yet unknown quantity stored at the La Hague site, at the MOX fuel fabrication facilities in Cadarache and Marcoule (France), Dessel (Belgium) and at the UKAEA site of Dounreay in the form of fresh breeder fuel.

The Hesse Government has requested that the Hanau facility be decommissioned and the plutonium moved to another site. Negotiations between the operator Siemens, the Federal government and the Hesse government have led to the understanding that all the plutonium should be transferred from Hanau before year 2000 and that delays would be costly for both Siemens and Bonn[41].

Table 13: German Plutonium Stored at Hanau (kg)

Form	Quantity (kg)
"MOX fuel assemblies held for utilities"	1,090
"Other reactor fuel"	250
Liquid plutonium nitrate	70
Plutonium oxide	490
MOX powder	500
TOTAL	**2,400**

(Source: Nucleonics Week, 15 August 1996)

If the largest share of the German plutonium stockpile is currently stored outside the country, the disposition of German plutonium at Hanau leads to similar questions as in the Dutch case. The solutions currently discussed are the transport of the plutonium to another German site or to a MOX fabrication facility or even back to the La Hague reprocessing site.

It is quite obvious that most of the "solutions" have the negative implication of exporting the problem to another country. We will discuss details hereunder for the Dutch case.

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[41] *Nuclonics Week,* 15 August 1996.

The Management of Plutonium Which Has Already Been Separated from Dutch Spent Fuel

Technically there are various possibilities to dispose of separated plutonium, and in particular manufacturing into MOX fuel and disposition as waste.

• The **fabrication of plutonium into MOX fuel** elements. This is the option which has the obvious support from the plutonium industry. Dutch plutonium could be sold or given to a foreign utility which has the possibility and the will to use MOX fuel in its reactors. Currently there is no incentive for MOX fuel use. All the parameters are negative if one compares MOX with uranium fuel:

- MOX fabrication is five times or more as expensive as uranium fuel fabrication[42] which makes the use of MOX fuel globally much more expensive than that of uranium fuel;
- MOX complicates the reactor operation (it needs particular attention, remote control and handling capacity because of higher neutron radiation, requires recalculation of the core neutronics and is less flexible for electricity grid following than uranium fuel);
- MOX complicates fuel management (two types of fuel instead of one, restrictions on burnup increase which is in direct contradiction to the tendency with uranium fuel, etc);
- MOX complicates physical protection and safeguards at the plants (fresh MOX is considered as direct weapons use material because it is relatively easy to separate plutonium out from MOX);
- spent MOX is significantly more radiotoxic and contains five times as much plutonium than spent uranium fuel and therefore needs specially equipped transport/storage containers.

In other words, MOX use is only accepted by utilities if they are under strong political or economical pressure to use it, which is the case when a country or a utility has constitued a large surplus of plutonium. But one can hardly imagine why any utility should accept the use of more MOX than it has to use - that is using more plutonium than what it has produced itself and what it has under its responsability. Therefore one has to consider that a foreign utility should be paid for - rather than it having to manage any costs - to use MOX incorporating Dutch plutonium. If that is the case there might be also strong public opposition in the respective country against the acceptance of "foreign" MOX.

For instance, in the US, the Department of Energy is to fincancially compensate the few utilities which will use MOX fuel during the experimental programme to compare plutonium disposition options.

This still leaves the question of the final destination of the *spent* MOX. Is it to be returned to the Netherlands? If it is returned, what if there is a cladding failure or any other technical problem, which would make the transport

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[42] There are several internal industry documents confirming this point. Jean-Beaufrère, then assistent director of EDF's nuclear fuel division made a similar statement in an Interview with Mycle Schneider on 11 May 1989

particularly dangerous or even impossible? If it is not returned, what country would accept the storage of foreign nuclear waste on its territory? France can be ruled out immediately because the Law prohibits the definitive storage of foreign radioactive waste. So where to go then?

• The **disposition of plutonium as waste** is one of the official plutonium disposition options, besides the MOX option, identified by the US Department of Energy for weapons plutonium disposition (also recommended by the US National Academy of Sciences). The basic principle is the mixture of plutonium with liquid high level radioactive waste to make it proliferation resistant and subsequent vitrification (or solidification in another matrix like ceramics). This technology is currently being experimented at the US Savannah River site, some experience exists also in Russia.

There are multiple advantages to this option. The basic vitrification technology exists and is operational at various sites in Europe, in France at La Hague and Marcoule, in Belgium at Mol and in the UK at Sellafield. A new vitrification facility is being built at the Karlsruhe research center in Germany which could be adapted right from the early stages of the conception to plutonium vitrification.

Another possibility is the manufacturing of plutonium fuel pins which would replace spent fuel pins in spent fuel elements. The plutonium pins would not visually be identifiable and would be in a highly radioactive environment which make them basically as proliferation proof as spent fuel. The disadvantage is that the process would necessitate to manipulate hot spent fuel elements needing considerable specific infrastructure.

Economically the waste conditioning solution is probably cheaper than the MOX option, even if one takes into account that there are still some technical difficulties to be dealt with (plutonium dissolution, acceptable share of plutonium...). The Dutch utilities and the government would have to negotiate with governments and industry in France, Belgium, UK or Germany as to the conditions under which they could accept the plutonium waste conditioning in their respective country. Under any circumstances the waste would have to be returned to the Netherlands after conditioning. But the waste product would be very similar to the high level vitrified waste canisters which are to be returned from Sellafield and La Hague anyway.

The Management of Plutonium Which Has Not Yet Been Separated from Dutch Spent Fuel

The best management for plutonium inside spent fuel is to leave it there, i.e. not to reprocess the spent fuel. This would mean considering the spent fuel as nuclear waste and managing it as such. The large majority of the spent fuel discharged from nuclear reactors worldwide is not covered by any plutonium separation programme and will follow a direct storage strategy. In fact, given the failure of the fast breeder reactor, there is practically no utility honestly considering plutonium production as a cost effective or reasonable option from an energy resource and waste management perspective. This is still difficult to admit for utilities tighed into long-term plutonium production schemes developed twenty years ago. That the world's plutonium producers COGEMA in France, BNFL in the UK and Minatom in Russia continue to claim the impossible benefits of the plutonium economy is a normal phenomenon. On the contrary, the Japanese plutonium producer PNC has become fairly modest after a series of incidents revealed mishaps and mismanagement and the government threatened the company in its mere existence.

There are several ways of avoiding plutonium separation under current reprocessing agreements.

• The most logical way is to **cancel the reprocessing contracts** and to recover spent fuel which has already been sent to Sellafield and La Hague. There are two different quantities of spent fuel corresponding to two different reprocessing agreements:

- The fuel under base load customer contract to be executed until about 2000 which has not yet been reprocessed (77 MT);
- The fuel under the post-2000 contract, which is planned to be reprocessed after the year 2000 (156 MT).

The baseload customer contract is a cost-plus-fee contract which essentially means that most of the money probably would have to be paid even if the contract is not carried out. (Although it should be stressed that the precise amount to be paid for by Dutch utilities would have to be set in a court case if there is no agreement between parties). There is clearly no legal element which would allow COGEMA to *carry out* the plutonium separation and *not allow* the return of the spent fuel against the will of the customer. Several in-depth legal analyses have shown this in the past.

The post-2000 contract is probably analogous to the contracts signed by German utilities with COGEMA and BNFL in 1990. The authors have obtained copies of the respective framework contracts. These agreements contain a political "force majeure" clause which enables the utilities to withdraw from them without any or almost no penalty fee in case of government intervention of their respective States. They also indicate that in the event that the utilities withdraw from the contract on their own initiative, they are required to pay penalty fees which increase the closer the contracts are cancelled to the scheduled reprocessing.

• The reprocessing contracts can also be **sold, subcontracted or swapped**. Considering that the prime level of decision is economic and industrial in nature (and leaving ethical considerations aside), economically the most favorable solution is the sale or the subcontracting of the reprocessing contracts. This is particularly true for the baseload customer contracts to be carried out until 2000. The sale of the contract or its subcontracting would allow to recover all or most of the investment carried out under the cost-plus-fee contracts with COGEMA and BNFL.

The other solution would be to swap the contract with another utility for a given quantity of unreprocessed spent fuel which is unsuitable or less suitable for reprocessing (high burnup fuel, MOX, re-enriched reprocessed uranium fuel...).

A precedent has been created by the Swedish utilities during the 1980s. They are publically out of reprocessing and appear in none of the tables of COGEMA customers anymore, while they had originally signed baseload contracts. They nevertheless stayed baseload customers and continue to participate in the baseload customers meetings. They merely subcontracted a given quantity of fuel to be processed now by other utilities (Germany, probably Japan). At least part of the spent fuel under the Swedish original contract has been swapped against spent German MOX fuel considered difficult to reprocess. In other words, Sweden has accepted to receive German spent MOX fuel for final storage in Sweden in exchange of an "equivalent" quantity of Swedish spent fuel which the German utilities delivered to COGEMA for plutonium separation.

The possibilities to sell, subcontract or swap reprocessing contract seem very attractive. The only major problem is to identify an interested utility willing to take up the contracts. To our knowledge the number of utilities willing to get rid of their contracts is significantly larger than the ones potentially interested in picking up existing contracts of other utilities.

Obviously the ethical dimension of the transfer to another utility of a Dutch plutonium contract has also to be debated. However, that is beyond the scope of this report.

SUMMARY AND CONCLUSIONS

The Netherlands are in the quite unique situation to have a small nuclear programme - one reactor at Dodewaard which was shut down in March 1997, and one reactor at Borssele which is scheduled to be phased out by 2004. However shutting down nuclear power plants does not solve the problem of the management of the spent fuel which has arisen from the operation of the reactors during their lifetime.

The Dutch utilities had based their spent fuel management strategy on the separation of plutonium to be used in fast breeder reactors. All the spent fuel to be discharged from the two Dutch reactors was planned to be reprocessed. In the early 1970s and also more recently, various contracts have been signed with companies operating plutonium production facilities in Mol in Belgium, in Sellafield in the UK and in La Hague in France.

In parallel the Dutch utilities had taken shares in the Germany based European fast breeder reactor consortium SBK (Schnell-Brüter-Kernkraft-werksgesellschaft m.b.H.) which was the builder-operator of the Kalkar reactor and a shareholder in the France based Superphénix builder-operator consortium NERSA.

The complete failure of the European fast breeder reactor programme - Kalkar never operated and Superphénix is definitely shut down - has led to a problematic situation concerning the management of plutonium being produced under existing contracts.

The present report gives an overview of origins and stocks of Dutch plutonium and analyses various management options. Some of the possibilities outlined in the report are innovative and have not been subject to in depth consideration so far. In order to confront the problems linked to select and carry out such options, which can be considered "the least bad options" for the various situations, an uncommon portion of political courage is needed.

Dutch Plutonium Production

Dutch separated plutonium stems from reprocessing contracts with the French plutonium producer COGEMA (for Borssele fuel) and the Belgian Eurochemic plant or the British THORP plant (for Dodewaard fuel). The reprocessing contracts correspond to almost all the spent fuel production from the two reactors until their respective definitive shut-down.

Borssele

• 85 MT of spent fuel were reprocessed at the UP2 plant at La Hague before year 1990.

• 140 MT of spent fuel are under contract for reprocessing in the UP3 at La Hague, of which 77 MT were reprocessed as of 1 March 1997.

• 156 MT are under contract for reprocessing after year 2000 at La Hague.

Dodewaard

• 8 MT were reprocessed at the Belgian Eurochemic plant prior to its shut down in 1974.

• 53 MT (approximately) are under contract for reprocessing after year 2000.

Therefore a total 442 MT of fuel were under reprocessing contracts of which 170 MT were processed as of 1 March 1997. We estimate the quantity of **plutonium separated** through the reprocessing of that quantity of fuel to be about **1,670 kg**.

Dutch Plutonium Use

Where has the separated plutonium gone? About **4 kg of Dutch plutonium** have been sold to the Belgian firm Belgonucléaire for testing purposes as early as 1972.

Some of the Dutch plutonium separated under reprocessing contracts abroad has been used within the **European fast breeder programmes**.

• It can be supposed that **174 kg Dutch plutonium were incorporated in the Kalkar fuel** produced in Belgium and that this plutonium is currently stored at the UKAEA Dounreay site.

• About **158 kg**, in three batches **of Dutch plutonium**

- **68 kg** to COGEMA in 1980
- **43 kg** to SBK in 1984
- **47 kg** to SBK/NERSA in 1985

have been transferred for use in **Superphénix** between 1980 and 1985. However, according to its share, the Dutch utility SEP should have contributed about 200 kg for the first two Superphénix cores which is substantially more than what has been transferred according to published information.

• An additional amount of **328 kg Dutch plutonium** has been **sold to the Italian utility ENEL** which owns one third of Superphénix for use in the same reactor.

Dutch Plutonium Stocks

The Netherlands have a current stock of plutonium and would have to manage significantly more separated plutonium if the total quantities of spent fuel under contract are reprocessed and if the breeder fuel from Kalkar and Superphénix are also recovered.

• The total **stock** of unused **separated Dutch plutonium** as of 1 March 1997 (according to available information) is about **1,000 kg,** all of which originates from the Borssele reactor (under the hypothesis that none of the Dodewaard fuel has been reprocessed so far) and all of it is probably **stored at the French La Hague site**.

It should be noted here that the term "sold" for Dutch plutonium which has been used in the fast breeder programmes is somewhat confusing, and probably misleading, and this for two reasons:

- The principle ruling the plutonium contribution scheme to the cores of Superphénix and Kalkar was the pro-rata contribution according to the shareholding distribution. Each shareholder and therefore plutonium contributor was to receive in return a pro-rata part of electricity and plutonium produced by the respective reactor.
- The European legal situation on nuclear materials is governed by the Euratom Treaty which stipulates that all nuclear materials stay the property of Euratom as represented by the Euratom Supply Agency.

• In addition to the plutonium already separated, current reprocessing agreements covering about 281 MT of spent fuel provide for the production of an **additional 2,750 kg of separated plutonium**.

• In principle a quantity of plutonium equivalent to the share of Dutch utilities at Superphénix and Kalkar builder-operator consortiums will be returned to the Netherlands after reprocessing of the fuel. Therefore this would mean an additional quantity of **over 200 kg to be recovered from Superphénix fuel** - some of it of **excellent weapons grade** quality - and the return of the **174 kg supplied for Kalkar fuel** which was never used.

--> Potentially the Netherlands will have to deal with over 4,000 kg (4 metric tonnes !) of separated plutonium.

One has to distinguish the situation of plutonium which has already been separated, and the plutonium which is still inside non reprocessed spent fuel.

• We estimate the **stockpile of separated plutonium in Europe as of 1 January 2000** to be at least **120 MT.** To illustrate the order of magnitude, this quantity is equivalent to:

- the annual production of 480 nuclear reactors;

- 20 full cores for a fast breeder reactor of the Superphénix type;
- about 12,000 nuclear warheads.

This plutonium stockpile is due to last. Considering that other countries would be willing to pick up and manage the Dutch plutonium stockpile seems far off reality. All the European countries involved in plutonium programmes today have plutonium production agreements inherited from the seventies which lead to this gigantic stockpile. No country can be interested in picking up additional plutonium quantities because of the many liabilities induced.

Destinations For Dutch Separated Plutonium

Any plutonium strategy for Dutch plutonium has to be considered in taking into account the huge plutonium stock which has built up and continues to grow in Europe.

We have discussed two potential destinations for Dutch separated plutonium:

• The fabrication of plutonium into plutonium-uranium mixte oxide or **MOX** fuel. Unfortunately MOX could not be used in Dutch reactors and there is no incentive for other utilities to use MOX fuel without being obliged to. MOX fuel use in comparison with uranium fuel use has proven:
- economically significantly more expensive;
- complicating reactor operation;
- complicating fuel management;
- complicating physical protection and safeguards;
- increasing significantly the radiotoxic inventory per spent fuel element.

Besides these points, MOX fabrication and sale to another utility would leave the fundamental question of the destination of the spent MOX fuel assembly. What country would accept not only all the negative impact of MOX use but also the final storage of the spent fuel on top of it?

• The **conditioning of plutonium and its disposition as waste.** Plutonium has currently a zero or even negative economic value. Therefore its conditioning as waste is one plutonium management option in the US as in various other countries. The already separated Dutch plutonium could be shipped to an existing facility - e.g. a high level radioactive waste vitrification facility like at Mol - to be mixed and vitrified with highly radioactive waste and be stored and treated thereafter with the other high active waste packages. There is currently a high active liquid waste vitrification plant project under development at the German Karlsruhe research center. This would be the appropriate timing to start negotiations into the conditioning of Dutch plutonium at such a facility.

Management Of Dutch Unreprocessed Spent Fuel

As in the case of already separated plutonium, there are various potential management schemes for Dutch spent fuel currently covered by reprocessing contracts but not yet processed.

• The most logical way is to **cancel the reprocessing contracts** and to recover spent fuel which has already been sent to Sellafield and La Hague. There is no question about the feasability of the action. Legal arguments have not proven substantial to prevent a utility from withdrawing from its reprocessing contracts. It is merely an economic and - above all - a political question. Contracts covering the period until about year 2000 have to be paid for to a large part under any circumstances because there are of "take-or-pay" nature. Post-2000 contracts most probably can be easily cancelled by the utility even without severe penalties under the condition that the utility withdraws as early as possible and that the government prohibits further plutonium separation.

• The reprocessing contracts can also be **sold, subcontracted or swapped**. Apart from ethical considerations, the contracts covering the reprocessing of Dutch spent fuel could be sold or subcontracted to another utility. Theoretically it is also possible to swap a given contract with another utility - as carried out by Swedish and German utilities in the past - for a given quantity of unreprocessed spent fuel which is unsuitable or less suitable for reprocessing (high burnup fuel, MOX, re-enriched reprocessed uranium fuel...). However, given the low current interest in plutonium, it is not very likely that the Dutch utilities would find an interested party.

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The decisions which are to be taken on the future management of Dutch plutonium and spent fuel are of very serious implications for the long term. The plutonium industry has led utilities all over Europe and Japan into a dangerous *fait accompli* situation. Gigantic stockpiles of plutonium are building up and will continue to build up if there is no drastic change in the plutonium industry.

The Dutch government and the utilities involved today have the opportunity to forge an innovative response to this unprecedented challenge. Whatever decisions are taken, it seems fundamental to base them on a large public approval which will only be reached under the condition that the democratic decision making process is considerably opened up. The present report is meant to constitute a small contribution to this debate.

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