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Study

Extension of Dutch Reprocessing:

Upholding the Plutonium Industry at Dutch Society's Expenses?

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The basis of current decisions on Dutch reprocessing extension is a misleading account of the past, present and future consequences of the Dutch reprocessing option at global and national level. In fact, the record and prospects of reprocessing show problems with the material balance, waste production, environmental impact and economics of this option that must be taken into account when assessing the Dutch spent fuel management. Moreover, the specifics of the Dutch situation, especially regarding the management of separated plutonium and uranium, further impede the rationale of the current strategy. Also, the whole assessment of the Dutch spent fuel management must be replaced in the global trend towards the end of large foreign reprocessing contracts in Europe. This clearly puts the Dutch society at risk of serving the interest of the reprocessing industry at its own expenses.

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Main Findings and Conclusions

Dutch reprocessing: a Countercurrent Strategy

From the early years, the Dutch nuclear utilities have participated in the development of the European plutonium industry. Major setbacks in its successive programs have not yet undermined the commitment of the Dutch nuclear industry to reprocessing. Nevertheless, the status of the Netherlands' spent fuel and waste management strategy must be placed in the broader context of nuclear decline and reprocessing crisis in Europe.

Altogether, the Dutch utilities have signed contracts for 382 t with the French operator of La Hague, COGEMA, covering roughly all the spent fuel unloaded from Borssele up to now, and 57 t with the British operator of Sellafield, BNFL, covering all the spent fuel unloaded from Dodewaard up to its shutdown in 1997 (in addition to 8.5 t of Dodewaard fuel reprocessed earlier in the Belgian plant of Dessel/Mol). These quantities represent the smallest foreign reprocessing contracts for commercial reactors fuel.

Although "recycling", especially that of plutonium contained in spent fuel, is the basis of the original rationale for reprocessing, the Netherlands did not develop this option. After the failure of the fast breeder program, in which they participated by providing Dutch plutonium for the fabrication of fuel for the German reactor Kalkar (that never operated) and the French reactor Superphénix (that was shutdown in 1998), they envisaged the use of mixed oxide fuel, or MOX (made of plutonium and uranium) in light water reactors, a solution that other utilities developed as a stopgap.

But the plan to burn MOX fuel in Borssele, that was once used as an argument for the reactor to be left running past the 1st January 2004 deadline, is now declined by the operator, EPZ, on the ground that the new deadline set for the reactor's shutdown, 2013, is too short for developing the required program. Nevertheless, EPZ announced on 1st March 2004 an "extension" of its reprocessing contracts, pursuing a fait accompli strategy based on announcements with no implementation perspectives.

However, the strategy pursued by EPZ seems to ignore serious problems encountered by the European plutonium industry. None of the four other historical foreign clients (Germany, Japan, Switzerland and Belgium) of reprocessing with COGEMA is to sign new reprocessing contracts, leaving the French company with an actual quantity of foreign oxide fuel (i.e. fuel from light water reactors) left to be reprocessed under contract of 1,300 t. This corresponds to less than one year of the plants' capacity, and is the lowest quantity ever in the order book since La Hague first reprocessing contract 30 years ago. The same is likely to apply to MOX fuel fabrication in the coming years.

Even the French national utility, EDF, which will remain up to 2007 under current contracts the overwhelming client of COGEMA reprocessing and MOX services, is now considering scaling back its program under economical pressure, linked to the opening of the electricity market and the planned privatization of the company. In the UK, economic pressure was already disastrous for BNFL, now faced with even darker perspectives for its reprocessing and MOX activity.

The strategy now developed by EPZ, which consists in reprocessing without any prospect for plutonium re-use, is therefore countercurrent to the European context, where the Member States of the European Union that used reprocessing services tend, mostly driven by active or latent policies of nuclear phase out, to give up this option and turn to a direct disposal strategy, and try to manage their own stock of separated plutonium through limited MOX fuel programs.

EPZ's commitment to the reprocessing option should also be assessed in the framework of a comprehensive strategy for present and future spent fuel and nuclear waste management. The Netherlands have developed an interim storage site, the COVRA facilities, destined to receive and store in a safe way, over a century, Dutch radioactive waste – including that arising from the spent nuclear fuel management.

However, the design of COVRA is in some ways inconsistent with the current status of the nuclear policy and spent fuel management in the Netherlands. In first place, the existing capacities are not sufficient to include high level waste (HLW) arising from the extension of Borssele's lifetime to 2013. Also, the choice for reprocessing, leading to enclose radioactive residues in a glass matrix, is somewhat contradictory with the objective of retrievability that COVRA is about. Finally, it is not clear whether the COVRA's facilities are prepared to receive all the kind of material arising from reprocessing waste that may be returned.

Reprocess to Recycle: the Broken Myth

The decline and dark perspective of the reprocessing industry in Europe and worldwide is linked to problems encountered with the reprocessing and "recycling" industry, most of them applying in the specific case of Netherlands. In fact, most of the assumptions supporting the "plutonium dream", from the nuclear energy and uranium resources outlook to the assessment of safety, security, environmental impact and economical cost of the reprocessing option, have proven dramatically flawed.

Because recycling is the most important, if not the only, justification for reprocessing, it should be assessed in details. The use of MOX fuel in light water reactors was developed as a stopgap after the failure of the original program commercial reprocessing was about, i.e. the perpetual mobile of plutonium "recycling" in fast-breeder reactors. However, using MOX as reactor fuel is a very inefficient and limited way to re-use the plutonium. In fact, the real balance of materials in the European plutonium industry shows the "recyclable" materials, plutonium and uranium, actually pile-up. None of the reprocessing clients has been able to at least stabilize its stocks of separated plutonium and uranium since the beginning of the reprocessing activities. In fact, the most advanced countries, France – which operates 20 of the 35 reactors using MOX in the world – and the United Kingdom – which does not even use MOX fuel in its reactors –, are those with the highest plutonium stockpile.

From the point of view of waste management, the presentation by the reprocessing industry that it reduces the 100% of irradiated spent fuel to a mean 3 or 4% of waste, i.e. the minor actinides and fission products that remain once the plutonium and uranium have been separated, is misleading. When taking all the waste produced in the reprocessing process, and the secondary waste of the MOX fuel chain into account, reprocessing of spent fuel appears to make the waste management more complicated by multiplying the categories of waste to be dealt with. In fact, experience in both the French and the British reprocessing industrial centres confirm the difficulties encountered in the management of the wastes arising from the reprocessing processes.

As a general rule, the usual safety, security and environmental problems linked to nuclear power and radioactive waste are heightened by the reprocessing option, as it introduces the separation of some of the most dangerous nuclear materials and multiplies the operations of handling, transport, conditioning and storage.

In first place, the separation of plutonium is a threat to international security. Contrary to an argument regularly put by the reprocessing industry and its clients, the plutonium of so-called "reactor grade", is perfectly usable for the making of bombs, as is unambiguously stated by international and national agencies such as the International Atomic Energy Agency (IAEA) or the US Department of Energy (DOE). Regarding accidents, especially due to external hazard, and potential terrorist attacks, the industrial development of specific storage and transport operations linked to the reprocessing option exposes European populations to higher risks. Also, reprocessing operations release considerably larger volumes of radioactivity than other nuclear activities, typically by factors of several 1,000 compared with nuclear reactors.

Finally, reprocessing and plutonium re-use are very costly options. Savings due to reprocessing – reduced consumption of natural uranium and enrichment services – as compared to direct disposal are very questionable when examined at global level (i.e. for a given number of nuclear reactors over their lifetime) and under real industrial conditions. The comprehensive study of the economics of the entire nuclear fleet completed for the French Prime minister in 2000, which offers very valuable results for the comparison of fuel cycle costs, clearly concludes from the economic point of view, the French industry should change its strategy for direct disposal, and the earlier the better – with savings estimated to 11-12% of costs that remain to be covered, even though France has massively invested in the reprocessing industry.

Dutch Spent Fuel Management: at the Crossroads

The end of historical reprocessing contracts provides the Netherlands with the opportunity to consider several management alternatives for the spent fuel that will arise form Borssele's operation until the end of its lifetime, currently planned by the authorities in 2013. This should combine with an open assessment of the legacy of past and present reprocessing options and the way it could be managed.

While only part of the Dutch spent fuel has been reprocessed, , the Netherlands are already faced with the legacy of the reprocessing option: the long term management of separated plutonium and uranium on one hand, and of various radioactive waste on the other hand.

Out of a total quantity of about 550 t of Dutch spent fuel expected over the two reactors lifetime, around 55% has been reprocessed, 27% has yet to be reprocessed (of which around 16% already stored in reprocessing plants, and 11% to be delivered) and 19%, still to be unloaded, is not covered by disclosed contracts. Large quantities of high level waste, intermediate level waste and low level waste from reprocessing, as well as separated uranium and plutonium, has already been produced and is to be produced through ongoing reprocessing.

One of the biggest challenges facing the Dutch nuclear industry will be the management of the separated plutonium stock that it has accumulated. EPZ's statement that the company will get rid of its stock by selling it to other companies is totally unsubstantiated in view of the long term trends in the so-called plutonium industry: separated plutonium (as well as reprocessed uranium) is given a nil value in official books of asset of EDF in France or BNFL in the UK, while EDF clearly stated a few years ago that there was no market for plutonium and that, even if there was, the plutonium value would be rather negative.

The main other issue with reprocessing legacy is the great uncertainties that remain as to the type, quantity and quality of the waste to be eventually received from reprocessing countries, and on the schedule for those returns. No waste from reprocessing has up to now been returned to the Netherlands, and the only public plan for return concerns the vitrified waste. However, as long-term storage of foreign waste is illegal in France, under a 1991 law, it must therefore be taken into account in the Dutch waste management policy that some, possibly all of reprocessing waste corresponding to the quantities reprocessed at La Hague shall eventually be returned.

As all the rationale of the origins has vanished, and the other European clients step out, the relentless pursuit of the Dutch reprocessing option is a risky policy, when COGEMA already faces the economical pressure of its prominent client EDF. Moreover, the example with BNFL shows that there is a real risk of a financial crisis of the French reprocessing industry, which could leave EPZ with high stranded costs and technical headache.

The stand-alone choice of EPZ for the reprocessing option in the coming years also represent a political risk that is not inconsiderable in Europe and on the international scene. The Netherlands could be blamed for their continuing support to the reprocessing industry and its huge radioactive discharges into the atmosphere and into the see, contrary to their commitment to the binding objectives of the OSPAR Convention, which they approved. Regarding international security, the

Netherlands could bear some political responsibility in the case some nuclear materials be diverted to military programs or terrorist groups, as reprocessing is under growing focus of the international community for increasing proliferation risks. The Netherlands could also be challenged on their support to reprocessing on the grounds of the safety and security issues, and bear some of the liabilities in the case of a severe accident in the European reprocessing industry or a terrorist attack against it.

It is therefore time to re-assess the spent fuel management strategy, taking full account of the legacy from past choices. Considering the limits in the design of COVRA, that require new storage capacities to be developed anyway, the international trend in spent fuel management, and the feasability and economics of spent fuel dry interim storage, this option should preferably be assessed and implemented, on the basis of operational experience in North America and current developments in European countries such as Germany or Switzerland.

In addition, regarding the task of managing the reprocessing legacy, the options for the disposal of the Dutch stockpile of separated plutonium should be discussed as a matter of urgency. In view of international experience, one option of particular interest may be the use of the MOX fabrication plants to produce so-called "mis-MOX", or bad MOX, i.e. MOX fuel assemblies using separated plutonium and possibly reprocessed uranium, and to store it together with spent uranium fuel so as to use the physical protection of its heat and radioactivity, in accordance with safeguards and so-called "spent fuel standard".

1. Dutch reprocessing: a Countercurrent Strategy

From the early years, the Dutch nuclear utilities have participated to the development of the European plutonium industry. Major setbacks in its successive programs have not yet undermined the commitment of the Dutch nuclear industry to reprocessing. Nevertheless, the status of the Netherlands' spent fuel and waste management strategy must be replaced in the broader context of nuclear decline and reprocessing crisis in Europe.

1.1. The Netherlands' Commitment to Reprocessing

The Netherlands are a quite atypical player of the plutonium industry. Although the quantities of spent fuel involved were lower than for other countries – in relation to the limited scale of the Dutch nuclear programme –, the country's operators have kept actively committed to reprocessing from the early years. Today, with only one operated pressurized water reactor (PWR) at Borssele, of gross electric capacity of 481 MWe, Netherlands are the country that reprocesses its spent nuclear fuels with the smallest nuclear fleet in the world.

Supplied by the Siemens-Stork union, Borssele's construction started in 1969 and commercial operation started in 1973 with the historical operator EPZ (NV Electriciteits-Produktie Maatschappij Zuid, formerly called PZEM). As soon as 1976, EPZ signed its first reprocessing contracts with the new-formed French company COGEMA. Over a 12 years period, this contract, as part of a batch of foreign contracts called "Baseload", covered a total quantity of 85.1 t of spent nuclear fuel to be reprocessed in the La Hague UP2-400 reprocessing plant currently shutdown.[1]

Quickly, a second reprocessing contract, as part of a new batch called "Service Agreement", was signed in 1981 and extended in 1993 for a total quantity of 140.9 t to be reprocessed in the foreign-financed UP3 facility at La Hague. In fact, the five countries – Japan, Germany, Switzerland, Netherlands and Belgium – that had participated to the first French commercial reprocessing activities for uranium oxide fuels, during the 70s in the first industrial-scale installation UP2-400, band together in the late 70s to set up one of the biggest European plutonium adventure. Form its start-up in 1989 until the late 90s, the UP3 plant, with a nominal capacity of 800 t/year, operated quite exclusively for the reprocessing of foreign spent nuclear fuels.

In 1993, the Netherlands participated again in the batch of foreign reprocessing contracts called "Post Service Agreement", for a total quantity of 156 t of Dutch spent fuel to be reprocessed mainly in the UP3 plant. With this last contract, the Netherlands totalized 382 t of spent fuel contracted over a period of about 30 years at La Hague. These quantities represent the smallest foreign reprocessing contract for commercial reactors fuel.

The Netherlands have also signed contract with the other European reprocessing company, BNFL, through their second operator, GKN. GKN operated the small boiling water reactor (BWR) at Dodewaard, with 58 MWe gross capacity, that started in 1969 and ceased commercial operation in 1997. The contract covers a baseload quantities of 57 t to be reprocessed in Sellafield. According to the information gathered, it seems all of the fuel was delivered to the UK site but only a small part of it, if some, has been reprocessed up to now.[2]

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[1] Most figures on the time of Dutch reprocessing contracts and the quantities covered are, among other but rare sources, taken from *Kamerstukken*, "Opwerking van radioactieve materiaal", Letter from Minister of Economic Affairs, 25 June 1997, 25422, n°1.

[2] Under "commercial secret", no information is available from BNFL. However, GKN published on its website the detail of the transports of Dodewaard spent fuel to Sellafield (111 in total, comprising 982 fuel elements, or all of the contracted quantity), completed in April 2003.
According to estimates by the Cumbrians Opposed to a Radioactive Environment (CORE), as of July 2000,

In the early years of the reprocessing industry, the Netherlands also participated in the Eurochemic reprocessing program, by sending some irradiated fuel for reprocessing at the plant of Dessel/Mol, in Belgium, which operated from 1957 to 1974. In total, GKN had about 8.5 t of Dodewaarde spent fuel reprocessed in the plant.

Although "recycling", especially that of plutonium contained in spent fuel, is the basis of the original rationale for reprocessing, the Netherlands did not develop this option. Unlike most of other reprocessing clients, the Dutch nuclear industry has given up plans to use the separated plutonium in MOX fuel (a fuel of "mixed oxides", plutonium and uranium, in a rough proportion of 5-95% to 10-90%, to be loaded in light water reactors in place of the standard uranium oxide fuel, or UOX).

A demonstration program of MOX use in Dodewaard was however conducted before the reactor's shutdown in 1997, but it only involved small quantities. The most significant attempt to use some of the separated Dutch plutonium has been its transfer to the European fast breeder reactors program, the participation of the Netherlands to this program being actually the reason for starting Dutch reprocessing. Dutch plutonium was used in the fabrication of the fuel of the fast-breeder reactors Kalkar in Germany and Superphénix in France. However, as the former never operated, and the latter was definitely shut down in 1998, the failure of the fast-breeder technology in Europe leave the reprocessing clients with no other use for the plutonium than the loading of MOX fuel in operating light water reactors.

But the plan to burn MOX fuel in Borssele, that was once used as an argument for the reactor to be left running past the 1st January 2004 deadline (previously set by the government), is now declined by the operator, EPZ, on the ground that the new deadline set for the reactor's shutdown, 2013, is too short for developing the required program.[3]

Nevertheless, EPZ announced in an official statement on 1st March 2004,[4] after the issue was disclosed earlier in 2004 through parliamentary work,[5] that it had "extended" its contract for reprocessing of spent fuel with the French operator COGEMA. No detail was provided on the content and the actual status, in political and commercial terms, of the decision. However, the successive annoucements by the Borssele's operator are revealing of the pursuit of a fait accompli strategy based on indefinitely postponed promises.

1.2. The Crisis of the European Reprocessing Industry

The status of the Dutch reprocessing programme and the analysis of the options for future spent fuel management must not be separated from the European level. If the strategy pursued by EPZ seems to ignore serious problems encountered by the European plutonium industry, those have dramatically altered the context which it could be based on.

• COGEMA's reprocessing contracts

In particular, as its smallest reprocessing contractor for commercial fuel, EPZ's strategy must be coherent with the trends in COGEMA's plutonium activities. The reprocessing activity for foreign

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the *"original reprocessing schedule given in the 1995 NAC International report show[ed] that contracted fuel from [the Netherlands] was not scheduled to be reprocessed at THORP until 2002"*.
See CORE Briefing, "Status of THORP Baseload Contracts", 23 March 2001.

3 According to A. MacLachlan, *"Nico Dekker, then nuclear affairs director at EPZ, said in late 1999 that Pu recycle could be the best argument to keep the reactor operating"*. But in June 2002, *"Jan Wieman, fuel cycle manager at EPZ, said that (...) the utility has now decided that re-launching a MOX licensing and irradiation program would take too long to be justified, given the 2013 scheduling horizon"*. See *Nuclear Fuel*, "Dutch utility EPZ no longer sees MOX use as an option at Borssele", Vol. 27, n°12, 10 June 2002.

4 EPZ news release, "Energieproducent EPZ verlengt contract voor opwerken", 1st March 2004. In another news release, "Containers met gebruikte splijtstofelementen op transport", on 3 March 2004, EPZ also announced that two containers, each filled with 7spent fuel assemblies, were sent to France.
See: http://www.epz.nl/site/www/main_right_content.php?id=0203#

5 *Nuclear Fuel*, "Dutch utility announces renewal of reprocessing with Cogema", Vol. 29, n° 6, 15 March 2004.

clients is globally declining since the early 80s, when all the 5 foreign clients signed the second batch of contracts. The first two batches amounted for 2,150 and 6,840 t of foreign spent nuclear fuels to be reprocessed in the UP-400 and UP3 plants respectively. The early 90s post service agreement contracts can be considered as a last jump of the reprocessing activity, for a total quantity of only 1,750 t, thus even below the quantities contracted in the framework of the first batch.

Since then, two reprocessing contracts have been completed, as of the end of 1999 for the Japanese clients, and as of the end of 2001for the Belgian client, with the fulfillment of all the contracted quantities. Japan, La Hague's second biggest client never signed a third contract, and has no plan to sign one, as it developed its own reprocessing capacities at Rokkasho-Mura.[6] In Belgium, where a law on nuclear phase-out was passed in December 2002, decision has been made to give up reprocessing and develop interim storage of irradiated fuel.

The German reprocessing contracts are still ongoing, but as the basis the country nuclear phase-out law passed in 2002, the June 2001 agreement between the Government and the electric utilities forbids German spent fuels shipments to La Hague after July 2005. Therefore it is clear that the German post agreement service contracts (signed in 1990 and 1996) will be the last COGEMA's reprocessing contracts for German customers.

If officially Switzerland does not rule out reprocessing as a possible way for spent fuel management, there is undoubtedly a growing pressure on this issue with several rejected votings aimed at ending the reprocessing of Swiss spent fuel. In fact, a moratorium period of 10 years will begin in Switzerland in July 2006 on the question of reprocessing during which the shipments of spent nuclear fuels for reprocessing will be forbidden. Moreover the moratorium period could be renewed for another 10 years by a simple federal decree. In practice, the legal situation put an end to the prospect of new Swiss reprocessing contracts.

The detail of the contracts signed by foreign utilities with La Hague for the reprocessing of light water reactor spent fuel is given in **Annex 1**. The Netherlands weigh for only 3.6% of the total quantities of foreign fuels contracted under the three successive batches of contracts. Figure 1 shows WISE-Paris estimates, based on the quantities contracted and reprocessed, of the evolution of the total "stock" of light water reactor spent fuel to be reprocessed by COGEMA under foreign contracts. As of the end of 2003, the quantities of such fuel still to be reprocessed under contract have been the lowest ever since the first contract signed for reprocessing at La Hague, 30 years ago. The remaining quantities are of the order of 1,300 t, which is less than one year of capacity of the whole La Hague reprocessing complex, or 20 months operation of the UP3 plant at full capacity, or between 3 and 5 years of operation at the rate of foreign fuel reprocessing in the recent years.

The controversial development of "processing" contracts for other types of nuclear material is not likely to reverse this global trend in terms of quantities. For instance, the agreement signed in January 1999 with the Australian Nuclear Science & Technology Organisation (ANSTO) is about the reprocessing of only 3.6 t of research reactor spent fuel. COGEMA is also used to store various unirradiated residues from the MOX fabrication plants that are supposed to be reprocessed in the future. Again, this activity can not sustain alone the operation of the whole La Hague complex.

The role of La Hague's historical and biggest client, the French electric utility EDF, already weighing for roughly two third of current reprocessing activities, is therefore to become even more preponderant. However, the future strategy of EDF, after the contract, based on an agreement signed in September 2001, running up to the end of 2007 for a total contracted of 5,250 t, is now under review.[7] Although officially an increase in quantities is discussed with COGEMA, the real issue is to reduce additionnal costs and provisions in the prospect of EDF's change of status (from state-owned utility to a commercial company), in a law to be passed in the coming weeks, and partial privatization, anticipated next year, both to prepare for tougher competition on the open electricity market. The financial pressure casts doubts on the real future of EDF's plutonium option.

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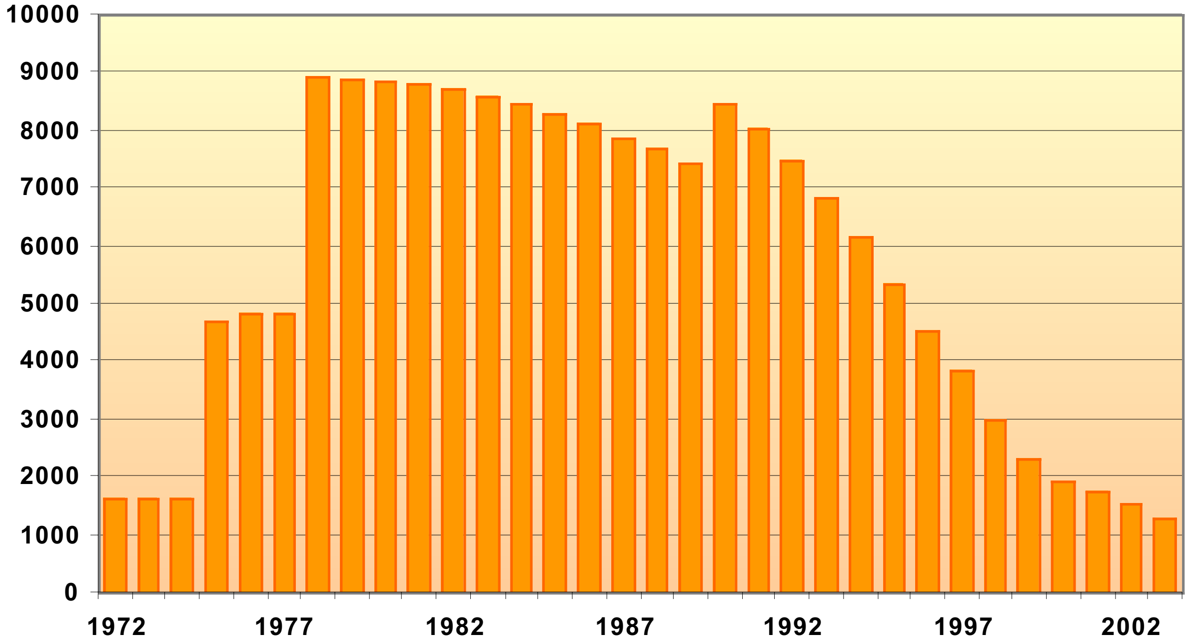
6 The long-delayed commissioning of the reprocessing plant of Rokkasho-Mura, designed after COGEMA La Hague's plant, is now planned for the coming year.

7 *Nuclear Fuel*, "EDF seeking more reprocessing, one-time payment to Cogema", Vol. 29, n°10, 10 May 2004.

Figure 1 - Evolution of the quantities of foreign light water reactor spent fuel to be reprocessed by COGEMA in La Hague plants (1)



(1) Quantities estimated by the difference between the total quantities under contract and the total quantities already reprocessed, as of the end of the year.

Source: based on CSPI, 2003 ; GRNC, 2001 ; DGSNR, 2003

• COGEMA's MOX fuel contracts

The global picture of the reprocessing industry in Europe is depressive on the short term but also on the longer term as it seems that no restart of the plutonium industry can be awaited in the coming years. As a consequence, the MOX industry that gives part of its justification to COGEMA's reprocessing activities faces similar challenges that will harden in the coming years. The long-awaited closure of the old ATPu Cadarache MOX production facility, that was exclusively working for German customers during the 90s, eventually turned into the "end of its commercial activities", without closure, in July 2003, while COGEMA obtained that the MELOX Marcoule plant nominal capacity be increased by 45% (from 101.3 to 145 tHM/year).[8] If this capacity transfer allowed COGEMA to fulfill its engagements with the German electric utilities, the German MOX contracts will come to an end with the termination of the German reprocessing contracts. It can be estimated that the annual German plutonium flow through COGEMA's plants is about 2.8 t, corresponding to roughly 250-300 t of spent fuel reprocessed and 40 t of MOX fabricated annually. These estimations show that the German reprocessing contracts could meet their fulfillment around the end of 2007, followed one year after by the end of the MOX contracts.

Until now, the only other potential MOX foreign clients for COGEMA, were the Japanese electric companies Kepco (Kansai Electric Power Co.) and Tepco (Tokyo Electric Power Co.). Since 2003, Kepco has announced that it intended to sign new MOX contracts to load the fuel in its two Takahama units around 2008 by the end of March 2004, likely with COGEMA, but as of June 2004, it seems no agreement was found yet.

Here again, the EDF's September 2001 contract, covering the fabrication of 625 t of MOX for the French company until the end of 2007, is of prime importance for the COGEMA's MELOX plant load

[8] *Investigation Plutonium*, "'Transfer'of MOX production capacity from Cadarache to Marcoule: one scandal after another", WISE-Paris, 8 September 2003.
http://www.wise-paris.org/english/ournews/year_2003/ournews030909a.html

factor. As it currently weighs here also for roughly two third of the plant capacity, the future of the French MOX industry is largely depending from the short term EDF's policy regarding the plutonium issue. As a consequence, a turn in EDF's spent fuel management as of the end of 2007, could have a very high impact on both the French reprocessing and MOX industries, with unforeseeable consequences on COGEMA's plutonium activities, including the eventuality of premature closures.

• BNFL's situation

As already pointed out, the Netherlands also contracted 57 t of spent fuel with British Nuclear Fuel Ltd (BNFL) to be reprocessed in its THORP facility at Sellafield which started operation in 1994. If all BNFL foreign reprocessing contracts are still ongoing, this does not mean that its situation is better than COGEMA. On the contrary, Sellafield position is even more uncomfortable as not only it suffers the total absence of new contracts, but also encountered (and still does) great difficulties to fulfill its operation planning, achieving only 40% of its nominal capacity of 1,200 t/year over the period 1994-2002. As of April 2002, only 3,900 t of spent fuel had been reprocessed in THORP.

The situation of the British plutonium industry is even worse since it has been severely hit by Japanese MOX scandals in October 1999. Moreover, the recent MOX plant, Sellafield MOX Plant (SMP), which started in October 2001, thanks to German contracts as justification of a minimal load factor, was threatened in January 2003 with the withdrawal of these contracts, leaving only few quantities of Swiss MOX to fabricate, on the plant schedule. In any case, it is very unlikely that SMP will ever meet its 120 t/year of nominal capacity, regarding the low interest of the foreign clients regarding British MOX – let aside the fact that the UK does not even use, or has plan to, MOX fuel in its own reactors. The recurrent problems encountered in reprocessing operation, of which the great safety and security problems caused by the storage of huge quantities of liquid high level wastes, together with unbearable cost weight for the electricity utility British Energy, have weakened the British reprocessing industry.

Among all nuclear wastes produced by the British nuclear industries, management of the plutonium industry wastes is the most problematic. If France encounters difficulties in managing its reprocessing wastes, the British plutonium industry is even threatened by its lack of management of its own wastes. In fact, in September 2001, the Sellafield reprocessing plants were temporarily shut down after the Nuclear Installations Inspectorate (NII) judged that volumes of liquid high level nuclear waste were reaching unacceptable levels[9]. However liquid high level waste vitrification is the most advanced conditioning program of the British plutonium industry, BNFL also encountered great difficulties to operate the plant at its full capacity.

As a consequence, it does not astonish that BNFL financial situation worsens year after year with a loss record for fiscal year 2004 of £ 303 million (more than € 460 million). To save the British plutonium industry, the new government Nuclear Decommissioning Agency shall take over responsibility for *"a significant portion of [BNFL] assets and liabilities as well as the legacy [cleanup] issues"* in April 2005.[10]

1.3. The Dutch Management of the Reprocessing Legacy and Alternatives

EPZ's commitment to the reprocessing option must be replaced in a global assessment of the Netherlands status and potential options regarding its spent fuel and nuclear waste management.

• EPZ's singular strategy

As shown in **Annex 2**, the Member States of the European Union that used reprocessing services tend, mostly driven by active or latent policies of nuclear phase out, to give up this option and turn to a

[9] *The Guardian*, "Sellafield shuts plants as N-waste builds up", 22 September 2001. See WISE-Paris news: http://www.wise-paris.org/english/othersnews/year_2001/othersnews010924.html

[10] M. Parker (BNFL Group Chief Executive), "BNFL Reported Today an Increased Loss for Fiscal Year 2004", in *Nuclear News Flash*, 10 June 2004.

direct disposal strategy. Moreover, this goes in some cases with the pursuit of MOX contracts, with the only purpose to manage some of the accumulated stocks of separated plutonium.

The potential extension of EPZ contracts for reprocessing of Borssele's spent fuel is therefore clearly opposite to the global trend towards the end of this option, especially at European level. Furthermore, the strategy now developed by EPZ, which consists in reprocessing without any prospect for plutonium re-use, is contrary to the reprocessing phase-out strategy of other foreign clients, which cease reprocessing first and try to manage their own stock of separated plutonium through limited MOX fuel programs.

In the light of Dutch long-time commitment to this option, the ongoing reprocessing may appear, from a national point of view, as the continuation solution. Given the risk that the Netherlands find itself the only foreign client of uranium oxide fuel reprocessing in the coming years, the European context should help not to consider this strategy as "business as usual" and reflect on some change in Dutch policy for spent nuclear fuel and nuclear waste management.

• The inconsistency of Dutch nuclear waste management

Reprocessing of spent fuel is not, in any case, the final stage of nuclear waste management. The Netherlands have developed an interim storage site, the COVRA facilities, destined to receive and store in a safe way, over a century, Dutch radioactive waste – including that arising from the spent nuclear fuel management (see a complete description of the facilities in **Annex 3**). However, the design of COVRA is in some ways inconsistent with the current status of the nuclear policy and spent fuel management in the Netherlands.

In first place, dimensioning of the COVRA's facilities destined to store high level waste (HLW), the HABOG bunker, was limited to the waste expected from the operation of the Dutch reactors taking into account the 1997 shutdown of Dodewaard and the projected shutdown of Borssele in the end of 2003. In other words, the existing capacities are not sufficient to include HLW arising from the extension of Borssele's lifetime to 2013.

Also, it is not clear wether the COVRA's facilities are prepared to receive all the material arising from reprocessing waste that may be returned. The HABOG facility is explicitly destined to store the vitrified waste that shall be returned from the La Hague and Sellafield reprocessing plants. But there is currently no detailed plan to use the facilities for the storage of other waste arising from reprocessing, although the capacity to store some of the intermediate level waste (ILW), was evoked in early communications about the Vlissingen's facilities.[11] However, if the center could manage such waste, there is no doubt that the COVRA facilities are not designed to store the separated plutonium and uranium piling up in reprocessing plants, which in the absence of a solution to be re-used may eventually return to the Netherlands.

Finally, the choice for reprocessing is contradictory with some of the objectives of the waste management implemented with COVRA. As an intermediate storage site, it constitutes a temporary solution for the Dutch radioactive materials and provides the Netherlands with a long period to consider all the possible management pathways toward a final solution. The retrievability of the wastes is a cornerstone of the COVRA plants conception because they must allow any future possible use of the stored nuclear materials. On the contrary, as opposed to the long-term storage of irradiated fuel, the process of vitrification of the highly and long-lived radioactive residues after reprocessing, destined to enclose them in a highly stable conditioning matrice, is practically forbidding any future extraction of the radioactive material.

[11] The possible management of cemented hulls and nozzles produced by the reprocessing of the Dutch spent fuel by COVRA is for instance mentioned in a May 1999 COVRA document: see J Welbergen, "Revised license for a radwaste facility in the Netherlands", COVRA, in *Southport'99, Proceedings of the June 14-18, 1999 International Symposium of the Society for Radiological Protection*, Southport, United Kingdom, 4 p.

2. Reprocess to Recycle: the Broken Myth

The decline and dark perspective of the reprocessing industry in Europe and worldwide is linked to problems encountered with the reprocessing and "recycling" industry, most of them applying in the specific case of Netherlands. In fact, most of the assumptions undergirding the "plutonium dream", from the nuclear energy and uranium resources outlook to the safety, security, environmental and economical assessment of the reprocessing option have proven dramatically flawed.

2.1. Uranium and Plutonium Stockpiling

Because recycling is the most important, if not the only one, justification for reprocessing, it should be assessed in details. In fact, if COGEMA claims that it recycles 97% of the spent nuclear fuels, the real balance of materials in the European plutonium industry shows a very different situation where the "recyclable" materials, plutonium and uranium, actually pile-up. None of the reprocessing clients, including the most advanced countries, France and the United Kingdom, has been able to at least stabilize its stocks of separated plutonium and uranium since the beginning of the reprocessing activities.

• MOX, the "recycling" stopgap

After the failure of the European fast-breeder program, the end of which was marked by the shutdown of Superphénix in 1998, the reprocessing industry developed the use of MOX fuel, a mixture of plutonium and uranium suitable for light water reactors, as a stopgap to use some of the accumulated stockpile of plutonium. There are about 35 reactors operating with MOX in the world (out of a total of 440 in operation), all of them in Europe.[12] For safety and security reasons, the use of MOX fuel requires a specific license, and its share is limited in the core to, depending on the country, between 25% and 50%.

In practice, the balance of the use of MOX fuel regarding plutonium show very low efficiency: the MOX fuel, which roughly contains between 5% and 7% of plutonium before irradiation, still contain 3% to 5% of plutonium after irradiation; in the meantime, the uranium oxide fuel (UOX) that completes the core contains no plutonium at the beginning and some 1% when unloaded. The global balance may be, as is for instance the case in current management of reactors using MOX in France, an increase in the total quantity of plutonium in the core (see the detailed figures, and how it compares to a core using only UOX, in **Annex 4**). An official assessment of the reprocessing option for the French Prime minister, in 2000, concluded that the reprocessing of spent fuel and re-use of separated plutonium would only reduce, over the French nuclear fleet lifetime, the total quantity of plutonium accumulated (in spent fuel) of a mere 15 to 20%.[13]

As the only regular user of MOX fuel at the scale of a large nuclear fleet, the status of EDF's policy on MOX use is also interesting. The use of MOX fuel in French reactors started in 1987, ten years after the start-up of the first of EDF's 58 pressurized water reactors (PWRs),[14] in 1977. Since then, MOX use has been extended in a limited way, and its energetic performance has been stagnating. EDF only got licenses to use MOX in 20 of the 28 reactors in its fleet that would be suitable, and it keeps the average loading in MOX of those reactors below the 30% limit.

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[12] According to Commissariat à l'énergie atomique, *Elecnuc - Edition 2003*, CEA, 2003. There are 20 in France, 10 in Germany, 3 in Switzerland and 2 in Belgium. This does not include a first MOX loading in Oskarsham, Sweden.

[13] Charpin, J.M., Dessus, B., Pellat, R., *Economic Forecast Study of the Nuclear Power Option*, Report to the Prime Minister, Commissariat général du Plan, Paris, July 2000. For more details, see last section of this chapter, on the economics of reprocessing, and global results in **Annex 7**.

[14] EDF operates 34 reactors of 900 MWe, 20 reactors of 1,300 MWe and 4 reactors of 1,450 MWe.

Altogether, the record of MOX fuel use in French reactors shows that operational quantities remain significantly below authorized and technically feasible levels, as illustrated in Figure 1. In the years 2000 and 2001, the number of MOX assemblies actually loaded in EDF reactors was less than two thirds of the number of MOX assemblies that could be loaded in the 20 authorized reactors (based on 16 assemblies reloads), and less than half of the potential number of assemblies that could be loaded in the suited 28 reactors of 900 MWe (see **Annex 4**).

• Separated plutonium stocks

Since reprocessing activities for the civilian nuclear industry have begun in France and in the UK, the global plutonium stock belonging to the main countries involved in those activities in Europe has been constantly rising, to reach a total of about 190 t of unirradiated plutonium.

Early plutonium stocks figures are not easily available, and the few existing figures would only provide some rare national trends. Reliable data only exist from 1996, through the compulsory declarations to the International Atomic Energy Agency (IAEA). The plutonium stocks of the main European client countries of COGEMA and BNFL for the 1996-2002 period are given in **Annex 5**.

This period is of high interest because of the peak in the European MOX fabrication during this timeframe. While all the European MOX facilities (COGEMA's ATPu plant at Cadarache and MELOX plant at Marcoule, and Belgonucleaire's P0 plant at Dessel) were in operation with load factors close to 100%, the plutonium stocks still increased. Altogether, the plutonium stock of France, the United-Kingdom and their clients Germany, Belgium, the Netherlands and Switzerland has increased by 45% between the end of 1996 and the end of 2002 (from roughly 133 t to 191 t), for a mean rate higher than +6% per year. Moreover, if the United Kingdom, which does not fabricate MOX fuel for a national use, is excluded from those calculations, the mean rate of increase is close to +7% per year over the same period.

It is not possible to calculate the global recycling rate of plutonium for the European plutonium industry in the frame of the present report. The calculation has been detailed for the French case over the 1956-1998 period. The assessment for the French plutonium only, showed that less than 50% of the separated plutonium had been recycled by the MOX, fast breeders and military programs over the period.[15] These figures confirm the inability of the plutonium industry to properly manage the by-products that it generates, and explain the global increase trend of separated plutonium stocks for all the reprocessing client countries.

• The embarrassing reprocessed uranium

Concerning the separated uranium issue, any analysis at a European level shall suffer a lack of detailed information, even if a global assessment of the situation can be depicted. In fact, as an industry historically bound to the extraction of plutonium, the reprocessing industry suffers severe deficiencies regarding the uranium issue. Separated uranium management was established a posteriori and has always been heavily challenged by the low prices of natural uranium. Moreover, due to the isotopic composition of the separated uranium (modified during the irradiation in reactor), the radioactive material raises some problems regarding the re-enrichment processes and the radioprotection. As a consequence, and according to the available information, France is the sole country to make a commercial use of reprocessed uranium fuel (ERU) in two of its 58 power reactors. Also some countries, including the Netherlands, have developed limited programs to use some reprocessed uranium,[16] France is the only one that could reach significant uranium-recycling rate.

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15 M. Schneider (Dir.), X. Coeytaux, *Recyclage des matières nucléaires - Mythes ou réalités*, WISE-Paris, May 2000, 24 p. When not only considering the plutonium separated by the French reprocessing industry, but also the plutonium contained in discharged spent fuel but not reprocessed, the global recycling rate fell to less than 19%.

16 The case of Netherlands is detailed in the next chapter. Germany tested some ERU assemblies for a total 31.8 t in the past but has no official program for the use of its reprocessed uranium, and Belgium had loaded 88 t of ERU in 1990.
See K. Hummelsheim, W. Mester, *Entsorgung abgebrannter Brennelemente aus den Kernkraftwerken in der*

It can be estimated that the French reprocessing plants alone had extracted roughly 29,500 t of uranium from the 30,800 t[17] of spent fuels reprocessed as of the end of 2003, of which around 20,500 t belonging to EDF. Over the 9,000 t of foreign separated uranium, not more than a few hundreds tons should have been re-enriched for a further use in power reactors in Europe (Belgium and Germany). Calculations made by WISE-Paris estimated that the overall recycling rate for the uranium (including foreign uranium) extracted in the French reprocessing plants should be under 10% over the 1956-1998 period.[18] A quick update estimation of this uranium-recycling rate (164.2 t of URE have been fabricated between the end of 1998 and the end of 2003) show that the global uranium recycling had not cross the 10% level as of the end of 2003.

2.2. Waste Management Failures

When comparing spent fuel management options, besides the "recycling" theory, the reprocessing industry usually argues of a positive impact on waste management by reducing the 100% of irradiated spent fuel to a mean 3 or 4% of waste, i.e. the minor actinides and fission products that remain once the plutonium and uranium have been separated.

This is a misleading presentation, that reduces the waste arising from reprocessing to the sole vitrified waste containing the residues of the spent fuel matrix. If the vitrified waste constitute the only category of high radioactive level wastes (HLW) – and the one that is explicitly planned to return to client countries –, reprocessing facilities usually produce or have produced many types of wastes in each of the lower categories, i.e. the intermediate level (ILW) and low level radioactive wastes (LLW). The former include cemented hulls and nozzles, bituminized waste from sludges, the latter technological waste from processing and contaminated equipment. The main categories of waste, their characteristics and the number produced per unit reprocessed are detailed in **Annex 6**.

Therefore, reprocessing of spent fuel, instead of a straightforward management of highly active and long-lived residues, appears to make the waste management more complicated by multiplying the categories of waste to be dealt with. In fact, experience in both the French and the British reprocessing industrial centres confirm the difficulties encountered in the management of the wastes arising from the reprocessing processes.

If the wastes currently produced at La Hague are for the vast majority conditioned and stored in dedicated interim storages, this cannot be considered as a long-term management solution. Moreover, large quantities of waste produced in the past, mainly LLW and ILW including hulls and nozzles, sludge and various exotic wastes, remain under non-conditioned forms, awaiting that COGEMA retrieve them from the pits and ponds were they have been sometime put together, and condition them. As shown in **Annex 6**, as of the end of 1999, for instance, about two thirds of the radioactive waste produced at La Hague, in volume, were unconditioned (or not satisfyingly conditioned). This share reaches more than four fifths of the waste produced at Sellafield.

One should also add to this total the secondary waste of the reprocessing option, i.e. those specifically arising from the fabrication and use of MOX fuel. This comprises, in particular, two categories: the by-products of MOX fuel fabrication, mostly the unirradiated MOX fuel scraps, and the irradiated MOX fuel that has been used in reactors. Although there is no industrial plan to reprocess those material and even less to re-use their plutonium and uranium, the only management strategy the plutonium industry has developed for those material is their return to La Hague for storage "in view of future reprocessing". COGEMA de facto transformed its La Hague installations into intermediate

Bundesrepublik Deutschland - Ergebnisse des Länderumfrage vom 31.12.2001, Gesellschaft für Anlagen und Reaktosicherheit (GRS), July 2002, 76 p.

[17] Of which 11,450 t of French Magnox fuel and 9,950 t of French uranium oxide fuel.

[18] M. Schneider (Dir.), X. Coeytaux, *Recyclage des matières nucléaires - Mythes ou réalités*, WISE-Paris, May 2000, 24 p.

storage facilities[19] for 433 t of spent MOX (of which 52 t belonging to German clients) and probably more than 100 t of MOX scraps (98 t as of 31 December 2001 was the last figures published by COGEMA, including 11 t of storage MOX from the German Hanau facility)[20] as of the end of 2003. The announcement, on 16 June 2004, by the German Federal Office for Radiation Protection (BfS – Bundesamt für Strahlenschutz), that the core of the Kalkar fast breeder reactor – which never went into operation – was going to be sent to the La Hague plant for reprocessing, is yet another step in that new strategy.[21]

The plutonium industry therefore leaves a legacy of numerous categories of waste of very different physical, chemical and radioactive characteristics that are currently stored with no definite perspective for final disposal. The issue remains open on how the responsibility will be shared between the reprocessing companies and their clients, including the foreign ones, for the management of this long term legacy.

2.3. Safety, Security and Environmental Problems

As a general rule, the usual safety, security and environmental problems linked to nuclear power and radioactive waste are hightened by the reprocessing option, as it introduces the separation of some of the most dangerous nuclear materials and multiplies the operations of handling, transport, conditioning and storage. The following is a review of the most prominent concerns, as they emerge in particular from reprocessing experience in Europe.

• The proliferation risk

If plutonium was firstly separated from spent fuels to make bombs, it became of interest for industrial purposes when reprocessing facilities progressively lost their military customers in the 60s. Then was developed the idea that plutonium could serve uranium economies and the myth of a closed fuel "cycle" indefinitely re-using plutonium.

However, the military potential of plutonium remains. Contrary to an argument regularly put by the reprocessing industry and its clients, the plutonium of so-called "reactor grade"[22] is perfectly usable for the making of bombs. This is unambiguously stated by international and national agencies such as the International Atomic Energy Agency (IAEA) or the US Department of Energy (DOE), which both consider any quality of plutonium, apart from nearly pure plutonium-238,[23] is usable to make a nuclear weapon. In a 1997 document, the DOE concludes that *"virtually any combination of plutonium isotopes - the different forms of an element having different numbers of neutrons in their nuclei - can be used to make a nuclear weapon. (...) In short, reactor-grade plutonium is weapons-usable, whether by unsophisticated proliferators or by advanced nuclear weapon states"*.[24]

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19 This issue was taken to the French courts by environmental NGOs, with no success. In the meantime, new licenses have been ordered for the COGEMA plants at La Hague that allow for the operator to develop this type of activity.

20 For detailed information see X. Coeytaux, E. Rouy, M. Schneider, *Secret Shipments and Illegal Storage – The Strange Story of Imported Waste at La Hague*, WISE-Paris, Briefing and Annexes, March 2001, 23 p.

21 *Lösung für nukleare Altlasten in Hanau, Bfs Räumt Plutoniumlager*, BFS Press release 11/04, 16 June 2004.

22 This does not refer to a specific difference between the plutonium used in military programs and that separated from spent fuel unloaded from reactors, as operated in the commercial reprocessing program today – in fact, the origin of military plutonium is the same. The definition of categories of plutonium usually refer to their quality depending on the level of plutonium-240: usual categories are "super grade" (2-3% plutonium-240), "weapon grade" (less than 7% plutonium-240), "fuel grade" (7-18% plutonium-240) and "reactor grade" (over 18% plutonium-240).

23 Typically the plutonium separated from standard uranium oxide fuel unloaded from a light water reactor would contain around 2% plutonium-238; this share would be around 3% for the plutonium contained in irradiated MOX fuel from a light water reactor.

24 See US Department of Energy, Office of Arms Control and Nonproliferation, 1997, *Final Nonproliferation and Arms Control Assessment of Weapons-Usable Fissile Material Storage and Excess Plutonium Disposition Alternatives*, Washington, DC: DOE, DOE/NN-0007, January, pp.37-39.

Regarding the quantities required, there is also no ambiguity in the position of the International Atomic Energy Agency (IAEA), which considers that 8.5 kg of plutonium constitutes the “significant quantity” from which the possibility of making of a bomb cannot be technically excluded. [25]

In a large MOX fabrication plant like MELOX, in France, a theoretical active insider, working at the weighing of the master blend, the first step of the MOX fabrication process, who would divert 1 g of each weighed kilogram of plutonium, could near the “significant quantity” in one year. The example of the Tokai Mura (Japan) reprocessing plant, of 100 tHM/yr of capacity which started operation in 1977, could be a good illustration of the material balance precision. In fact, Japanese officials acknowledged in January 2003, that it took a 15-year investigation to account for a more than 200-kilogram shortfall in plutonium at the reprocessing plant.[26] From the 6,890 kg separated by the plant during its 25 years of operation, roughly 3% escaped to the operator material balances.

• Safety and security issues

Among the specific risks raised by the reprocessing industry, one of the main concern is the handling of the very dangerous separated plutonium. The very high radiotoxicity of plutonium, for instance, would increase the health impact of a severe accident affecting a nuclear reactor loaded with MOX fuel.

Also, plutonium is, in terms of lower limit for the quantities needed, highly subject to criticality. For example, as compared to 60 kg for low enriched uranium (3.5 % uranium-235), the quantity beyond which the criticality risk is considered substantial falls down to 500 grammes only in the case of plutonium-239.[27] On more than 60 criticality accidents in nuclear installations worldwide, since 1945, 12 criticality accidents involved plutonium, causing in official accounting 4 deaths and 37 significant irradiations.

Regarding accidents, especially due to external hazard, and potential terrorist attacks, the industrial development of specific storage and transport operations linked to the reprocessing option also exposes European populations to higher risks.

Among the nuclear facilities located on the French territory, the scenario of a targeted plane crash on COGEMA’s La Hague facilities would be the most extreme in terms of impact on the environment and public health: the spent fuel reprocessing facilities in the Nord-Contentin represent in fact an inventory of radioactive substances several orders of magnitude larger than that of a nuclear power station. The site is in particular used to store thousands of tons of irradiated fuel, tens of tons of separated plutonium and thousands of cubic meters of radioactive wastes.

The impact analysis is a rather simple evaluation of the order of magnitude, because it assumes identical dispersion conditions as in the case of the Chernobyl accident. Considering the exposure scenarios of the Chernobyl accident, the result then obtained, based solely on the stock of cesium in pool D (one of the 5 cooling ponds), shows that a major accident in this pool could have an impact up to a few tens times that of the Chernobyl accident with a fraction release equal to 100%. In other

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One can also quote Hans Blix, then Director of the International Atomic Energy Agency (IAEA) who, in a letter of 1 November 1990 to Paul Leventhal, President of the Nuclear Control Institute, Washington D.C., USA, wrote: "*The Agency considers plutonium from irradiated fuel with high burn -up rate and in general any isotopic composition of plutonium, with the exception of those containing more than 80 per cent of plutonium-238, as being usable for an explosive nuclear device.*"

[25] The IAEA defines the "*significant quantity (SQ)*" as "*the approximate quantity of nuclear material for which, taking account of the necessary conversion processes, the possibility of producing an explosive nuclear device cannot be excluded*".

[26] Associated Press, “Missing plutonium probe latest flap for Japan's beleaguered nuclear power industry”, Tokyo, January 28, 2003. See WISE-Paris news: http://www.wise-paris.org/english/othersnews/year_2003/othersnews030128b.html

[27] IPSN, *Les accidents de criticité dans l’industrie nucléaire*, update of November 2001.
A low enriched uranium containing about 3.5 % of uranium-235 is quite typical of the quality of uranium used in standard fuel for most of the current reactors.

words, a release limited to only 1.5% of the stock of cesium in a half full pool D would be consequently comparable to the release of cesium during the Chernobyl accident.[28]

Of all of the categories of dangerous substances in general, nuclear materials, transported by hundreds of convoys each year, represent one of the most important sources of risk. Dangers in the handling and transport of plutonium arise from the risk of criticality (start of a fission reaction), the substance's high radio-toxicity, and from the problem of proliferation (theft of nuclear material to make atomic weapons). As illustrated by the events of 9/11 2001, the threat of terrorist activity targeting transport, or hi-jacking of plutonium for its use in a nuclear device or "dirty bomb" has now to be considered an increased risk. In a scenario of accident affecting a truck transporting plutonium oxide powder caused by an act of aggression, such as a heavy artillery attack on the plutonium-carrying truck, the fall-out area could be as much as 250 km^2 and could affect a population of 125,000 people in places such as the northern suburb of Lyon (France). Likely to cause 500 fatal cancers, this would require evacuation of part of one of the three largest French cities and its suburbs, with no hope of return for within a foreseeable period.[29]

The global radioactive pollution

Reprocessing operations release considerably larger volumes of radioactivity than other nuclear activities, typically by factors of several 1,000 compared with nuclear reactors.

Because releases of the reprocessing industries have not only a local impact, but because of a dilution-dispersion strategy, have also a diffuse, long range impact, countries that even do not have a nuclear activity, undergo the effects of the French and British plutonium industry. For example, Norway accused Britain of ruining its lucrative Arctic lobster business by failing to stop radioactive discharges from Sellafield,[30] and Ireland made a submission to the Hamburg-based International Tribunal on the Law (ITLOS) of the Sea in November 2001, against the United Kingdom, to prevent any further radioactive pollution of the Irish sea by the British plutonium industry[31], followed by other complaints filed to the Permanent Court of Arbitration.

A May 2003 report by the Radiological Protection Institute of Ireland (RPII) confirmed that radioactive discharge from Cumbria's Sellafield reprocessing plant continued to be the dominant source of contamination of the Irish Sea, two years after the case was submitted to ITLOS[32].

The September 2001 study on "Possible Toxic Effects from the Nuclear Reprocessing Plants at Sellafield (UK) and Cap de La Hague (France)", commissioned by the Scientific and Technological Options Assessment of the European Parliament, directed by WISE-Paris and co-authored by a team of nine experts from France, UK and United States, highlights some aspects of the La Hague releases management in the context of the OSPAR convention[33.] While the convention aims at reducing the radioactive releases in the North-East Atlantic to a zero target, COGEMA engaged and pursued a "zero impact" policy during the late 90s. As a matter of fact, La Hague releases globally increased

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[28] See X. Coeytaux, Y. Marignac, M. Schneider, *La Hague Particularly Exposed to Plane Crash Risk*, WISE-Paris, Briefing, 26 September 2001, 14 p.

[29] See X. Coeytaux, Y. Marignac, M. Schneider, et al., *The Transports in the French Plutonium Industry – A High Risk Activity*, February 2003, 101 p.

[30] *The Guardian*, "UK accused over Sellafield pollution", April 29, 2003. See WISE-Paris news: http://www.wise-paris.org/english/othersnews/year_2003/othersnews030429.html

[31] *Investigation Plutonium*, "International Tribunal for the Law of the Sea holds hearing on the Irish case against the UK over MOX facility on 19-20 November 2001", WISE-Paris, 13 November 2001. http://www.wise-paris.org/english/ournews/year_2001/ournews011115.html

[32] RPII, *Radioactivity monitoring of the Irish marine environment 2000 and 2001*, May 2003. http://www.rpii.ie/reports/2003/MarineReport20002001final.pdf

[33] The OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic entered into force on 25 March 1998. The Convention has been signed and ratified by all of the Contracting Parties to the Oslo or Paris Conventions (Belgium, Denmark, the Commission of the European Communities, Finland, France, Germany, Iceland, Ireland, the Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom of Great Britain and Northern Ireland) and by Luxembourg and Switzerland.

during the 90s, but stabilized in the very late 90s; this stabilization can be largely addressed to the slight decrease of industrial activity that the COGEMA La Hague reprocessing plants encountered since 2000.

However, some of the released radionuclide decreased over the same period, contributing to the COGEMA's "zero impact" policy. The STOA report highlighted that La Hague releases management consisted in swaps between radionuclides in the releases themselves, and in transfers of radionuclides from the liquid to the gaseous discharges, leading to a decrease of the short term local impact to the detriment of the long term, more diffuse, global impact. At the report public hearing, in April 2002 at the European Parliament, COGEMA backed its policy on the decreasing figures of local individual doses, argued that the global collective impact was a debated criterion and stated that it was anyway below other global impacts, such as aerial nuclear tests or exposure to natural radiations. However, the global impact transfer tendency demonstrated by the report was never put into question.

In the surrounding regions of Sellafield and La Hague a statistically significant increase in the incidence of leukemia has been established. While research on the causal relationship with environmental radiation has not been conclusive, it cannot be ruled out that exposure to radiation is an initiating or at least a contributing factor.

2.4. Dubious economics

Reprocessing is expensive. Savings due to this option – reduced consumption of natural uranium and enrichment services – as compared to direct disposal are very questionable when examined at global level (i.e. for a given number of nuclear reactors over their lifetime)[34] and under real industrial conditions.

The study of the economics of the entire nuclear fleet completed for the French Prime minister in 2000 offers very valuable results for the comparison of fuel cycle costs, for many reasons. Firstly, because France offers an utterly favorable context (early development of a fully integrated fuel cycle industry, with continuous political support, to become the world leader in the plutonium industry) where the economics of reprocessing can be expected to be optimized. Secondly, because the opening of the European electricity market has created a new pressure for competitiveness and a requirement for transparency on costs that put the French reprocessing option in question, especially from an economic point of view. Finally, because contrary to previous evaluations, the Mission report[35] adopts a global methodology, also based on a direct access to industrial data.

The assessment comprises both a reconstitution of the past (from 1977, when the first EDF commercial PWR started, to 1999) and a prospective evaluation of the future management of the facilities (from 2000 to the end of service life of reactors – 2049, with an operating life of on average 45-years). Scenarios for the future differ in particular for the later stages of the fuel cycle, with three main hypothesis:

- "partial reprocessing": pursuing of the present strategy, a dual one since only around 70% of the uranium fuel is reprocessed, with use of MOX in around 20 PWRs reactors as currently;
- "total reprocessing": extension of reprocessing to all uranium fuel, leading to use of MOX in the 28 PWRs (900 MWe) technically designed to use it;

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34 As opposed to the rather theoretical calculation that can be done, for instance, on the input and output of one typical reactor in one year.

35 Charpin, J.M., et al., *op.cit*. See also the annex report, Girard, Ph, Marignac, Y., *Le parc nucléaire actuel*, preparatory report to the Mission d'évaluation économique de la filière nucléaire, Commissariat général du Plan, Paris, 2000.
Instead of evaluating the only annual input and output of one reactor and extrapolate the theoretical result to the industrial scale. It directly estimates the material and economic balance of the current French nuclear facilities over their lifetime, on the basis of a year-to-year analysis.

• "end of reprocessing": abandoning of reprocessing and switching to a direct disposal strategy, with a final abandoning of reprocessing in 2010.[36]

Detailed results of the material and economic comparison of the scenarios are presented in **Annex 7**, together with the main hypothesis on costs used for the evaluation – which must be pointed as globally optimistic[37]. The fuel cycle[38] in the "total reprocessing" scenario, in comparison with the "end of reprocessing" scenario, produces additional costs assessed at around € 6 billion[39], representing € 120 million per year for the remaining years of the power plant service life, or as much as 11-12 % of costs that remain to be covered. The main finding of the report is therefore very clear: although the major part of the investment for the development of the reprocessing option has already been paid for, it appears that from the economic point of view, the French industry should change its strategy for direct disposal, and the earlier the better.

It must be stressed that these results, although they could be considered the most complete and relevant as a basis to the economics of the Dutch reprocessing option, are coherent with most of the recent studies on the costs of reprocessing published in the United States, France, UK or Japan.[40]

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[36] The Mission also considered and calculated a scenario of abandoning of reprocessing in 2001, but decided not to publish it, mainly for political reasons.
However, the additional cost of the reprocessing option is estimated by way of comparison with this fictional (for the retrospective part) scenario of "total direct disposal" of uranium spent fuel from 1977 to the end of lifetime of current reactors. The total savings of the direct disposal option in comparison to the "total reprocessing" scenario is € 25 billion: this difference in fuel cycle costs represents more than 5.5% of the total cost (investment, operation and fuel). The saving through direct disposal would be on average € 300 million per year over the total service life of the power plants, or around € 410 million per GWe installed. The cost advantage of the non-reprocessing option is also reflected in the average cost per kWh with 2.08 centimes against 2.20 centimes for the reprocessing option.

[37] For instance, the costs of reprocessing, or MOX fabrication, are considered for the operation at full capacity of the plants although in some scenarios this condition is not fulfilled.

[38] Investment and operational costs of the nuclear installations are supposed to be the same in all scenarios that are also adjusted to represent the same cumulated production of electricity.

[39] The savings are even higher, around € 7.5 billion, in a scenario where reprocessing stops in 2001.

[40] See for instance: Bunn M., Fetter S., Holdren J., et al. *The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel*, Managing the Atom Project, Belfer Center for Science & International Affairs, Harvard University, December 2003.
http://bcsia.ksg.harvard.edu/publication.cfm?ctype=book&item_id=351

4. Dutch Spent Fuel Management: at the Crossroads

The end of historical reprocessing contracts in the coming years provides the Netherlands with the opportunity to consider several management alternatives for the spent fuel that will arise form Borssele's operation until the end of its lifetime, currently planned by the authorities in 2013. This should combine with an open assessment of the legacy of past and present reprocessing options and the way it could be managed.

3.1. The Status of Dutch Spent Fuel Management

While only some of the Dutch spent fuel has been reprocessed yet, leaving the possibility open to develop alternatives for future spent fuel management, the Netherlands are already faced with the legacy of the reprocessing option: the long term management of separated plutonium and uranium on one hand, and of various radioactive waste on the other hand.

• Quantities of spent fuel reprocessed

As of 31 January 2002, which is the latest official update available, the first and second Dutch reprocessing contracts for Borssele spent fuel were fulfilled in their entirety, and the reprocessing of 43 of the 156 t to be reprocessed under the terms of the third contract was already achieved. At this time, 110 t of Dutch spent nuclear fuel were still to be delivered to the La Hague installations.[41] According to the low detailed information published by COGEMA on its web site, 6 shipments for a total of 6 Dutch spent fuel packages took place in 2002, 5 shipments for 9 packages in 2003 and 3 shipments for 6 packages until mid-June 2004.[42] Moreover, COGEMA published the figure of 15 t of Dutch spent fuel stored in La Hague cooling ponds as of 31 December 2003[43] and did not mention a priori any reprocessing of Dutch spent fuel between January and mid-June 2004.

With a rough estimation of 2.25 t of spent fuel per transport package,[44] it can be estimated that as of 15 June 2004, over 156 t of spent fuel contracted, 65.7 t were already reprocessed, 28.5 t were in storage in La Hague cooling ponds and 61.8 t were still to be delivered (corresponding to roughly 28 transport packages that could be shipped in 14 convoys according to the current rate of two packages per shipment). According to the current annual number of spent fuel shipments originated from the Netherlands and the transportation mode, all the Dutch spent nuclear fuel covered by the third reprocessing contract could be delivered until the end of 2005, or the first semester of 2006.

The total quantity of spent fuel discharged by the Dodewaard reactor until its closure amounts to 65.5 t of spent fuel, of which 8.5 t were reprocessed in the Eurochemic plant before its shutdown in 1974. The rest of the spent fuel (57 t) is due to be reprocessed in the BNFL THORP plant at Sellafield.

According to the Dutch government[45], the 382 t of spent fuel contracted by EPZ should have covered the total spent fuel production of the reactor, when considering the previously planned shutdown in 2003. This figures is correlated by the plant annual discharge of the order of 38 spent fuel assemblies (until 1998) with an initial uranium content of 321 kg, or 12.2 t of spent fuel per year. However, it seems that the introduction of a new fuel management since 1998 (reload by third to

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[41] Commission Spéciale et Permanente d'Information près de l'Etablissement COGEMA-La Hague, "Bilan d'exécution des contrats COGEMA avec les clients étrangers", in *Bulletin d'information*, n°10, April 2002.

[42] It should be noted that the figure for 2003 is contradictory with information from Dutch sources that 10 packages were transported to La Hague that year.

[43] COGEMA, *COGEMA-La Hague: Production et transport*, 30 March 2004.

[44] The figure corresponds to the heavy metal weight (HM) of the transport package, i.e. the initial content in uranium of the fuel. The total weight of a transport package is around 3.3 t.

[45] *Kamerstukken*, 25 June 1997, *op.cit.*

quarter of the 121 assemblies in the core), conducted to a current yearly discharge of 32 spent fuel assemblies. This would mean that considering the lifetime extension up to 2013, the Borsele reactor would still discharge around 10.3 t of spent fuel per year for a total of 103 t of spent fuel over the 10 years period. This does not count with the spent fuel that will remain in the reactor core at the date of shutdown (three quarters of the core according to the above calculation) or roughly 28.6 t, leading to a total of 131.6 t still to be unloaded, of which 103 t beyond the current reprocessing contracts.[46]

Altogether, management of the spent fuel from the two Dutch reactors of Borssele and Dodewaard is shared as summarized in Table 1. With the hypothesis that only small quantities of GKN spent fuel has been reprocessed at BNFL (therefore assuming the figure is close to zero), and considering an estimate of 291.7 t under contract with COGEMA have been reprocessed, the quantities of Dutch spent fuel already reprocessed, as of 15 June 2004, can be estimated of around 300 t (of which 8.5 t from Dodewaard and 291.7 t from Borssele). Given the quantities under contract, that means a total of around 147 t of the known contracted quantities, as of 15 June 2004, are still to be reprocessed in the UK (around 57 t) and France (an estimate of 90.3 t), of which 61.8 t are still to be delivered at La Hague. Moreover, about 103 t of fuel to be unloaded until the shutdown of Borssele are not covered by those contracts.

Table 1 - Past, present and future management for Dutch spent nuclear fuel

	Unloading		Management				
	Qty	**Status**	**Qty**	**Status**	**Reproc.**	**Of which (1)**	
GKN Dodewaard	65.5 t	Unloaded	8.5 t	Reprocessed	Mol/Dessel		
			57 t	Being reprocessed	Sellafield	~0 t	Reprocessed
						~57 t	Stored at Sell.
EPZ Borssele	382 t	of which (1)	85 .1 t	Reprocessed	La Hague		
	~352.4 t ~28.6 t	Unloaded To be unloaded	140.9 t	Reprocessed	La Hague		
			156 t	Being reprocessed	La Hague	~65.7 t	Reprocessed (3)
						~28.5 t	Stored at L.H.
						~61.8 t	To be delivered
	~103 t	To be unloaded (2)	~103 t	To be decided			

(1) Figures preceeded with "~" are WISE-Paris estimates, as of 15 June 2004.
(2) Considering the operation of the Borssele reactor up to the deadline of 2013.

Source: WISE-Paris 2004

[46] It is assumed here that the 1993 reprocessing contract, as it was supposed to cover all the spent fuel arising from Borssele's operation up to its shutdown in the end of 2003, would include the full core remaining at the end of operation. A rough estimate by WISE-Paris of the total quantities unloaded by Borssele shows that, assuming the core was unloaded, on a yearly basis, by third (38 assemblies) up to 1998, then by fourth (32 assemblies) up to 2003, the total quantity of fuel, including three quarters of the core remaining in the end of 2003, amount to about 384 t, therefore corresponding to the total quantities covered after the third reprocessing contract.
However, it should be noted that the calculation may have been different. Considering an average 40 assemblies unloaded by year from 1973 to 2003 (i.e. not considering the change of fuel management in Borsele in 1998, that may not have been included in the estimate when the reprocessing contract was signed, in 1993) gives a total amount of 384 t also, this time not including the remaining of the core as of the end of 2003.

Therefore, out of a total quantity of 550 t of Dutch spent fuel expected over the two reactors lifetime, around 55% have been reprocessed, 27% have yet to be reprocessed (of which around 16% already stored in reprocessing plants, and 11% to be delivered) and 19%, still to be unloaded, are not covered by disclosed contracts.[47]

• Quantities arising from past and current reprocessing contracts

Because of the lack of information on the reprocessing waste produced by the Eurochemic plant, the quantities of Dutch spent fuel reprocessed in the plant will not be included in the further estimations of reprocessing waste production for the Dodewaard reactor. Moreover, figures of the waste production for THORP remain unknown, notably because of the great difficulties encountered by BNFL in both reprocessing the spent nuclear fuels and managing the wastes productions. In the following, estimation of waste volumes arising from Sellafield reprocessing is therefore based on COGEMA La Hague figures and should only be used as an indication of the order of magnitude of the radioactive materials quantities that can be attended from the reprocessing of the Dodewaard fuel by BNFL.

Table 2 - Estimated waste and separated nuclear material arising from reprocessing of Borssele (EPZ) spent fuel at La Hague and Dodewaard (GKN) spent fuel at THORP

<table>
<tr><th></th><th colspan="4">EPZ / COGEMA</th><th colspan="2">GKN / BNFL</th></tr>
<tr><th></th><th colspan="2">Current status (1)</th><th colspan="2">Total contracted</th><th colspan="2">Total contracted</th></tr>
<tr><th></th><th>m³</th><th>Packs</th><th>m³</th><th>Packs</th><th>m³</th><th>Packs</th></tr>
<tr><td>HLW vitrified waste</td><td>37.9</td><td>211</td><td>49.8</td><td>277</td><td>7.3</td><td>41</td></tr>
<tr><td>Structural waste < 12.2001</td><td>134.5</td><td>90</td><td>134.5</td><td>90</td><td rowspan="2">28.0</td><td rowspan="2">19</td></tr>
<tr><td>Structural waste > 12.2001</td><td>3.0</td><td>17</td><td>14.8</td><td>83</td></tr>
<tr><td>Bituminized sludge (2)</td><td>64.8</td><td>309</td><td>64.8</td><td>309</td><td>22.4</td><td>107</td></tr>
<tr><td>ILW sub-total</td><td>202.3</td><td>416</td><td>214.1</td><td>482</td><td>50.4</td><td>126</td></tr>
<tr><td>Technological waste CBFC-2</td><td>102.1</td><td>87</td><td>134.1</td><td>114</td><td>19.6</td><td>17</td></tr>
<tr><td>Techno. waste CBFC-1 < 1995</td><td>259.2</td><td>220</td><td>259.2</td><td>220</td><td rowspan="2">78.4</td><td rowspan="2">67</td></tr>
<tr><td>Techno. waste CBFC-1 > 1995</td><td>181.6</td><td>154</td><td>309.4</td><td>262</td></tr>
<tr><td>LLW sub-total</td><td>542.9</td><td>461</td><td>702.7</td><td>596</td><td>98.0</td><td>84</td></tr>
<tr><td>Total</td><td>783.1</td><td>1,088</td><td>966.6</td><td>1,376</td><td>155.7</td><td>251</td></tr>
<tr><td>Separated plutonium (t)</td><td colspan="2">2.4</td><td colspan="2">3.2</td><td colspan="2">(3) 0.36</td></tr>
<tr><td>Separated uranium (t)</td><td colspan="2">279</td><td colspan="2">368</td><td colspan="2">53.6</td></tr>
</table>

(1) Based on WISE-Paris estimate, as of 15 June 2004.
(2) For reprocessing of EPZ fuel at COGEMA-La Hague, bituminized sludge before 1995.
(3) For Dodewaard spent fuel, on the basis of 264 kg of fissile plutonium for 57 t of spent fuel, according to: Tweede Kamer, *Brief Van de Minister Van Economische Zaken - vergaderjaar 1996–1997*, 25 June 1997.

Source: WISE-Paris 2004

[47] Although EPZ has announced an "extension" of the contract as of 1st March 2004, no indication has been given about if this would include new quantities, and how much. Therefore the estimates are based on the contracted quantities as published earlier.

According to COGEMA's figures of 1% of plutonium and 96% of uranium contained in the spent nuclear fuels reprocessed in the La Hague installations, the 291.7 t of Dutch spent fuel already reprocessed shall have produced around 2.4 t of separated plutonium[48] and 279 t of separated uranium. Moreover, COGEMA presents the figure of 1 canister produced for the reprocessing of 1.4 t of spent nuclear fuel. If this figure should be taken with carefulness, because it reflects only the up-to-date vitrification performances, it can be used to estimate that at least 211 canisters of vitrified waste were produced in the frame of the Dutch reprocessing contracts.

Applied to the EPZ contracts in their entirety, the above figures show that the 382 t to be reprocessed shall have produced around 3.8 t of separated plutonium, 368 t of separated uranium and at least 277 canisters of vitrified waste at the term of the fulfillment of past and current contracts.

According to the diverse figures and La Hague waste production history, the reprocessing wastes belonging to the Netherlands, already produced or to be produced within the frame of the current reprocessing contracts can be estimated.[49] The quantities to be expected are given in Table 2.

3.2. The Plutonium Headache

One of the biggest challenge facing the Dutch nuclear industry will be the management of the separated plutonium stock that it has accumulated.

• The growing Dutch plutonium stockpile

The Dutch operators, GKN and EPZ, although they used the "recycling" argument to promote reprocessing as the management option for their spent fuel, have both failed in implementing a route for re-using their separated uranium and plutonium. Moreover, after EPZ argued that it should not be shut down, as a mean to re-use plutonium through the loading of MOX fuel, the company simply gave up any MOX programme.

As a result of this fait accompli strategy, the management of the separated Dutch plutonium, especially that already physically separated in La Hague, is a major concern for the Netherlands. EPZ's statement that the company will get rid of its stock by selling it to other companies is totally unsubstantiated in view of the long term trends in the so-called plutonium industry.

In the early times of the European fast breeder programme, some Dutch plutonium was provided for the fabrication of the required fuel – this was, as Paul Leventhal, President of the Nuclear Control Institute, put it in a testimony before the Dutch Parliament in 1997,[50] *"the primary* raison d'être *of Dutch reprocessing"*. Altogether, 486 kg were provided for the fabrication of fuel for the French Superphénix reactor, and 174 kg for the German Kalkar reactor. Two cores were fabricated for Superphénix, of which only one was loaded and irradiated in operation before its shutdown in the end of 1998. The fuel fabricated for Kalkar was not irradiated, as the reactor never started.

In absence of any other solution to use the Dutch plutonium, the stockpile of separated plutonium is steadily growing as the reprocessing of Dutch spent fuel goes on. As shown on Figure 2, the quantities of separated plutonium from reprocessing of Dutch spent fuel at La Hague approach the total of 2.4 t, as of 15 June 2004, and should come close to 3.2 t when all the quantities covered by the current contracts are reprocessed. Furthermore, the choice of the reprocessing option for the 103 t that remain to be unloaded would separate around 0.9 t, letting the whole stock of Dutch plutonium go over 4 t.

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[48] According to , Tweede Kamer der Staten-Generaal, *Brief Van de Minister Van Economische Zaken - vergaderjaar 1996–1997*, 25 June 1997, the mean plutonium content of the Dutch spent fuel reprocessed at La Hague should be less than 1%, but rather 0.83% which is surprisingly low considering the current spent fuel management by quarter and initial enrichment of 4%.

[49] In order to highlight La Hague wastes management improvements since 1995, the figure of 162 t of Dutch spent fuel reprocessed as of 31 December 1995, given by COGEMA will be used.

[50] Testimony of Paul Leventhal, President, Nuclear Control Institute (NCI) on Reprocessing, Waste and Non-Proliferation. Presented to a Parliamentary Hearing of the *Tweede Kamer*, The Hague, The Netherlands, 24 October 1997.
http://www.nci.org/s/sp102497.htm

Figure 2 - Estimated stock of Dutch unirradiated plutonium arising from spent fuel reprocessing at La Hague

Source: WISE-Paris 2004

• The "negative price" plutonium market

The Netherlands have a growing stockpile of this "high energy potential" resource with no plan to use it. According to EPZ, the solution to this problem is as simple as to sell it. But the analysis of the current trend shows there is actually no market for this.

The other foreign clients of the reprocessing industry in Europe are engaged in a clear strategy of first, stopping reprocessing of their fuel to stop their separated plutonium stock increase, and in second, manage the existing stock through MOX fuel as long as it is possible – which means they are not looking for getting more of this material. The only major player that could possibly go on for some times with a plutonium program, including large scale reprocessing and MOX use, in Europe is EDF, which is faced with growing economic pressure to scale this program back and would not, if it goes on, increase the burden by buying some more plutonium.

Since the mid-90s, the separated plutonium – and the same applies to uranium – has been given a nil value in EDF assets, as published in the company's financial reports. In 2001, the British Government acknowledged the BNFL owned stocks of separated plutonium and reprocessed uranium *"were given a nil value"* in the National Asset Register.[51] In April 2000, Bernard Estève, then Director of EDF's Fuels Department, put it even more bluntly: when asked if the French national utility would be interested in buying some of the growing British stock of separated plutonium, he clearly stated there was no market for plutonium and that, even if there was, the plutonium value would be *"rather negative"*.[52]

[51] Answer of the then Secretary of State for Trade and Industry, Mr. Wilson, to a Parliamentary question. See House of Commons Hansard Written Answers for 22 October 2001.

[52] Quoted in *Nuclear Fuel*, Vol. 25 n°9, 1 May 2000.

• The long term legacy of separated plutonium management

Although the security and safety of the plutonium storage is under the responsibility of the storage site operators, like COGEMA at La Hague, and their national authorities, the plutonium remains, in principle, in the propriety of the Dutch companies that contracted reprocessing services, under the responsibily of the Dutch authorities. Therefore, the Netherlands should be committed to develop long term program for managing their separated plutonium.

Recent developments in the management of fast breeder fuel illustrate the dead-end of past plans of "recycling" and the long term legacy that their failure leaves. In May 2004, a public inquiry was held around the Superphénix site to get approval of the industry plan for its fuel management. The plan is to store the two cores, i.e. the irradiated and unirradiated assemblies, on site in a dry storage facility, for *"about the next 30 years"*. However, the material should, according to its official status, be regarded as a waste, since the industry claims it will be "processed", at the end of this interim storage, so that its plutonium and uranium content could be re-used – of course, with no further explanation. Although it is not clear if the plutonium remained the propriety of the foreign participants to the NERSA consortium, the operator of Superphénix, when it became a 100% EDF subsidiary, it may be that the Dutch are involved when the interim storage of this fuel comes to an end.

The announcement, on 16 June 2004, by the German BfS, that the core of Kalkar was going to be sent to the La Hague, and later Marcoule plants in France, in the framework of a contract between RWE over and COGEMA, is also of concern for the Netherlands as the unirradiated fuel contains Dutch plutonium. The transportation from Hanau – where the material is being stored – to La Hague should be completed by the beginning of the summer of 2005. It also states that the plutonium recovered from the Kalkar will be manufactured into MOX fuel to be used in RWE reactors, but there is no timeframe. The return to La Hague of separated plutonium , after traveling to Germany, that would be separated again while it remains unirradiated illustrates the folly of the reprocessing industry, and the responsibility taken by the Netherlands in participating this.

• The attempt to use reprocessed uranium (RepU)

Although the main concern, because of the risks associated, is with the management of separated plutonium, the reprocessed uranium, which arises in much larger quantities, must also be dealt with either by re-using it or by implementing its long-term management as waste.

With a total amount of around 420 t of reprocessed uranium expected to be separated trough the past and ongoing reprocessing contracts, the Dutch utilities have still to implement a large scale management of these stocks. However, EPZ has engaged in a program destined to re-use some of its reprocessed uranium. The August 2002 contract signed by EPZ with Framatome ANP which calls for the delivery of 36 assemblies fabricated by the Russian utility MSZ Elektrostal will not modify the Dutch uranium-recycling rate by factors. In fact, the fabricated fuel uses only reprocessed uranium to downblend Russian high enriched uranium (HEU) from submarine reactors and icebreaker fuel. According to the Russian Ministry of Atomic Energy (Minatom), around 400 of such assemblies have been produced for German and Swiss utilities since 1995. A rough estimation by WISE-Paris shows that around 11 t of uranium separated from Dutch spent fuel at La Hague could be used to fabricate the Russian-made "downblended-HEU-plus-Repu". According to Jan Wieman, EPZ fuel manager, EPZ has *"no intention to send any irradiated fuel back to Russia"*.[53]

3.3. The Problem of Reprocessing Waste Return

Great uncertainties remain as to the type, quantity and quality of the waste to be eventually received from reprocessing countries, and on the schedule for those returns.

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53 A. MacLachlan, "Dutch Utility EPZ Buys Russian Fuel Made From Blending HEU, Reprocessed Uranium", in *Nuclear Fuel*, Vol. 27 n°20, 30 September 2002.

• The illegal storage of foreign waste in France

There has not been, as of 15 June 2004, any return to the Netherlands of waste arising from reprocessing of Dutch spent fuel in France. The official schedule of the returns, which was pending the completion and licensing of the HABOG facilities by COVRA, only comprises, as exposed by COGEMA, the return of the vitrified waste. As of 31 December 2003, COGEMA planned one return per year for the next seven years, starting in 2004.

This supposes that all the other categories of waste produced by reprocessing would remain in La Hague and eventually be stored and disposed of in France. Such a fait accompli strategy would be strictly illegal regarding French law. A 1991 law, dedicated to the preparation of long term nuclear waste management, clearly stipulates that *"it is forbidden to store imported radioactive waste in France, even if it has been reprocessed on French soil, beyond the period of time technically required for reprocessing."*[54]

It must therefore be taken into account in the Dutch waste management policy that some, possibly all of reprocessing waste corresponding to the quantities reprocessed at La Hague shall eventually be returned, although the extend to which it could apply is not obvious yet. For instance, COGEMA's global management of Dutch ILW and LLW, together with the other foreign and French ILW and LLW, may be legally challenged. It could appear eventually that some or all the Dutch ILW and LLW could have been sent to the Centre de Stockage de la Manche (CSM) until its closure in 1994 and to the Centre de Stockage de l'Aube (CSA) since 1992. The return of the Dutch ILW and LLW could mean costly retrievals of the wastes from the CSM and the CSA.

Also, it should be noted that this does not only apply to the reprocessing waste such as fuel structures, dissolution fines and contaminated equipments. The law could extend, should they as it is likely not be re-used, to the stocks of unirradiated plutonium and reprocessed uranium. French MP Christian Bataille, regarded as the "father of the 1991 law", had declared in an interview with the *Le Monde* daily: *"The law [does not deal with] spent fuel awaiting reprocessing over a long period of time. This practice is contrary to the spirit of the law: materials not subject to industrial reprocessing should not be stored in France. As the father of this law, I argue that the spirit of the law is being flouted by this practice."*[55]

• The quality control issue

As of 1995, the Netherlands had only approved COGEMA's specifications for waste conditioning of vitrified waste. Approval was not granted for cemented hulls and nozzles, bitumized sludge, and cemented technological waste.[56] There has been no sign that this has changed in recent years. In fact, there is some reason to be cautious, in the perspective of the return of reprocessing waste, about the assessment of their "quality" by COGEMA's essentially non-destructive measurement.

In France as in most countries, no final solution has been decided for the management of the HLW and long-lived ILW. Researches are still ongoing and decisions have to be taken in 2006 (or later) in the French parliament. Only LLW and short-lived ILW benefit of final surface repositories but with unequal achievements. In fact, the first repository, the Centre de la Manche (CSM) near the La Hague facilities, which was closed in 1994, is far from the current requirements for storage facilities, not only regarding its basic design, but also regarding the waste quality control. As a consequence, the CSM shows already signs of leaks (notably tritium) and cover collapses, even if few waste rearrangements and impermeable structures were added before its closure.

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[54] *Loi n° 91-1381 du 30 décembre 1991 Relative aux recherches sur la gestion des déchets radioactifs*, Journal Officiel de la République Française,1st January 1992 (translateby WISE-Paris).

[55] Kempf H., "Le stockage en France de Mox allemand bafoue l'esprit de la loi" (Interview with Christian Bataille), *Le Monde*, France, 7 March 2001.

[56] According to Comité de Défense Civil, Guernsey, June 1995, quoted in Schneider, M. et al, *Possible toxic effects from the nuclear reprocessing plants at Sellafield (UK) and Cap de La Hague (France)*, STOA Report, European Parliament, November 2001. http://www.wise-paris.org/english/reports/STOAFinalStudyEN.pdf

The CSM episode underlines also a global problem of quality-control of the wastes produced by the reprocessing plants. In fact, the quality assurance procedures, used at La Hague as in any other industrial facility, are the only assertion of the quality and radioactive content of the wastes produced at La Hague. According to the available information, COGEMA does not proceed to periodic destructive controls of the wastes however thousands of wastes packages have been produced by the reprocessing facilities. As an example, only one destructive control was performed on samples taken on each of the two vitrification lines in 1992 and 1994 (R7 and T7 for UP2-800 and UP3 respectively) and probably none on the cemented hulls and nozzles packages or on the bituminized wastes. This lack of quality-control is of high importance regarding the return of the wastes in their countries of origin and to the storage management that will be set for centuries. Since March 2000, Belgium decided that it would be proceeded to a destructive control before the country would accept the endorsement of the vitrified wastes. The ONDRAF (the Belgian radioactive waste management agency) and the Mol research center were charged to set the quality-control programme in July 2000 but it seems that the half of a vitrified canister that should be studied at Mol has not been either produced nor transported yet (the second half should be studied by the CEA on the Marcoule site).

3.4. The Risks of a Reprocessing Extension and Its Alternatives

All the rationale of the origins – serving the European project of developing fast breeder reactors, anticipating on both ultimately wrong projections of a scarcity of uranium resources and a large and long-lasting nuclear generation development – has vanished. Even the attempts to replace it by the stopgap solution of MOX use in light water reactors is flawed, and could not be implemented in the projected lifetime of the only reactor still in operation in the Netherlands, now set to last up to 2013. Instead of the relentless pursuit of the reprocessing option, it is therefore time to re-assess the spent fuel management strategy, taking full account of the legacy from past choices.

• A hasardous future extension of the reprocessing option

A decision to extend EPZ reprocessing contract with COGEMA La Hague, for future Borssele spent fuel, would likely be a very singular strategy in Europe, leaving the Dutch utility as the sole foreign client for standard fuel reprocessing. Given the current rate of reprocessing at COGEMA's plants[57], the 90.3 t of Dutch spent fuel still to be reprocessed correspond to less than 3 weeks of La Hague activities. The extension of the reprocessing option to the 103 t still to be produced in Borssele, would represent less than an additional month of activity at the plant. In other words, the Dutch reprocessing contracts won't make the difference in La Hague future activity and the way it evolves.

This represents a high risk that, from a technical or economical point of view, the conditions of the reprocessing service become degraded. For instance, if it has not developed any alternative, the Dutch utility will have no choice but to accept the price and conditions imposed by COGEMA, which are likely to be less favorable than in the past – in particular given the pressure arising from EDF's dominant situation (where EDF's goal is to cut its costs in reprocessing, either by maintaining the current quantities with a lower unit cost or by reducing the quantities).

Moreover, the exemple with BNFL shows that there is a real risk of a financial crisis of the French reprocessing industry, which could result in the non execution of the contracts. This would leave EPZ with high stranded costs, the need to implement in urgency alternative routes for its spent fuel, and some problems with the management of the necessary retrieval of the nuclear materials left in France.

The stand-alone choice of EPZ for the reprocessing option in the coming years also represent a political risk that is not inconsiderable in Europe and on the international scene. This goes with the concern of European countries for the safety, security and environmental problems, which the Netherlands could be held responsible for as an active supplier of the reprocessing industry and the plutonium chain.

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[57] According to COGEMA, as of 2 June 2004, La Hague facilities had together reprocessed 631.4 t of French and foreign spent fuel from the beginning of the year, or an average of 40 t per week.

For instance, the Netherlands could bear some political responsibility in the case some nuclear materials be diverted to military programs or terrorist groups. In December 2003, the European Commission, which is under Euratom responsible for safeguards, reported that *"the annual Verification of the Physical Inventory of the COGEMA-Cadarache plant in France found an unacceptable amount of Material Unaccounted For (MUF) on the plutonium materials."*[58] This MOX fabrication plant, the ATPu, produced the Superphénix fuels, and is still used to store the unirradiated assemblies, including some Dutch plutonium.

The Netherlands could also be challenged on their support to reprocessing on the grounds of the safety and security issues, and bear some of the liabilities in the case of a severe accident in the European reprocessing industry or a terrorist attack against it. A problem that would occur in a reprocessing plant or a MOX fabrication plant, or in a plutonium transport, or even in a reactor loaded with MOX fuel would also give a strong blow to the reprocessing industry, likely to accelerate its decline and leave EPZ with no spent fuel management plan.

Finally, the Netherlands could be blamed for their continuing support to the reprocessing industry and its huge radioactive discharges into the atmosphere and into the see. In particular, the Dutch authorities must assume the contradiction between their full support to the OSPAR Convention and the fact that the UK and France, as the owners of BNFL and COGEMA, *"abstained, and are not therefore bound"* to the *"binding decision on the reduction and elimination of radioactive discharges, emissions and losses, especially from nuclear reprocessing"*, which *"requires the urgent review of current authorisations for discharges and releases of radioactive substances from nuclear reprocessing plants, with a view to implementing the non-reprocessing option for spent nuclear fuel management at appropriate facilities, and taking preventive measures against pollution from accidents."*[59]

• The necessary view on alternatives

The reprocessing option, that the Netherlands have taken up to now for the management of their spent nuclear fuel, leaves them with a high degree of uncertainty on the legacy of the past and a hazardous perspective for continuation. In particular:

- Regarding the waste arising from reprocessing, the quantities, type and quality, as well as the timetable of return, of the waste eventually to return to the Netherlands remain unknown. However, the storage facilities built by COVRA are not prepared to manage all that waste, in particular their dimensioning does not include the extension, for 10 years, of Borssele's operation.
- The stocks of Dutch separated nuclear materials, and in particular the highly dangerous plutonium, pile up with no other plan, after EPZ gave up the MOX option, than to sell it on a market that does not exist. After paying for separating it, it is likely the Netherlands will have to pay again for disposing of their stock, in a way that has still to be defined.
- The pursuit of the reprocessing option, that could leave the Netherlands as the single foreign client of uranium oxide fuel reprocessing services in Europe, therefore bears important risks in terms of cost, management and adverse political effect.

The problematic and unsolved legacy of the single-track Dutch spent fuel management should lead to a period of assessment before any further decision regarding the spent fuel that will arise from the Borsele operation until 2013. Moreover, this evaluation should include the current problems of management linked to separated uranium and plutonium stockpiles. Among all possible solutions, reprocessing consists probably in the less adapted and riskiest way regarding the Netherlands specificities.

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[58] Commission of the European Communities, *Report from the Commission to the European Parliament and the Council - Operation of Euratom Safeguards in 2002*, Brussels, 10.12.2003, (COM(2003) 764 final)

[59] OSPAR, *Further protection for the North-East Atlantic*, press notice of the OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic, 30 June 2000. http://www.ospar.org/eng/html/final_OSPAR_2000pressrelease.htm

If only 5 to 10% of world spent fuel arisings is submitted to reprocessing (the rest is stored pending final disposal in a repository), the number of countries relying on reprocessing to deal with their spent fuel has been declining since the late 90s.[60] Moreover, beyond the flexibility offered by the direct disposal option, nuclear utilities are moving towards dry storage solutions, including utilities in the US, Canada, Germany, Russia and many eastern European countries. In fact, the economic advantages of direct storage of spent fuel versus reprocessing are considerable.

For nuclear waste management policies, an important issue is the degree to which dry storage may be considered a viable long-term option for managing spent fuel. Dry storage in inert gas presents relatively few theoretical or practical difficulties. The IAEA has concluded after reviewing national experiences of dry storage that it is an acceptable waste management option for the storage of spent fuel for periods of 50 to 100 years.[61] By this time heat rates will have declined by about two orders of magnitude. The anticipated longevity of dry stores (50 to 100 years) is expected to exceed that of wet stores[62]. It is concluded that passive dry storage systems appear to be an acceptable means of managing spent nuclear fuel in the medium to long term. When reprocessing and dry storage are compared, large differences in costs become apparent: the former are clearly greater than the latter. US/Canadian storage systems are less expensive than European systems: US dry storage systems for PWR fuel are estimated to be 8 to 20 times less expensive per tonne than reprocessing.[63]

Considering the limits in the design of COVRA, that require new storage capacities to be developed anyway, the international trend in spent fuel management, and the feasibility and economics of spent fuel dry interim storage, this option should be preferred. It should be a priority task of the Netherlands authorities that the possibility for its implementation, and its consequences, should be carefully assessed.

Moreover, the dry storage solution should be considered in the light of the necessary Dutch plutonium immobilization. In fact, as it is highly doubtful that EPZ could clear its separated plutonium stockpile by selling it, the Netherlands will have to face decisions to manage its plutonium. If the MOX option is coherent with the single-track reprocessing choice, its implementation before 2013 seems quite unrealistic. In fact, the current fuel management of the Borssele reactor would not allow the introduction of more than 0.24 t of plutonium per year,[64] supposing that the reactor would obtain a license to proceed with MOX very quickly. The immobilization of the Dutch separated plutonium seems therefore to be unavoidable for at least part of the stockpile. Two major techniques can be applied to achieve such an immobilization complying with international safety standards. The first one studied in the case of the US-Russian weapon-grade plutonium disposal consists in mixing the plutonium in ceramic matrices forbidden any further extraction of the nuclear materials. However, this possibility is not suitable for immobilizing the separated uranium that comes in larger quantities.

The second option derives from the first one, as the ceramic matrix in question is none other than the one used to produce fresh MOX fuel. The German Öko-Institut developed the process called "storage MOX" where storage rods of MOX fuel (of low quality and therefore improper to any use in power reactors) are placed together with spent uranium fuel rods in storage packages[65]. Not only this process

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60 UNSCEAR, *Sources, Effects and Risks Of Ionizing Radiation*. UNSCEAR, Vienna. 2000 (See Annex C, Para 150 Page 188)

61 IAEA, *Nuclear Power, Nuclear Fuel Cycle and Waste Management: Status and Trends 1996*, Part C of IAEA Yearbook, IAEA, Vienna, 1996.

62 K.J Schneider, S.J Mitchell, *Foreign Experience on Effects of Extended Storage on the Integrity of Spent Nuclear Fuel*, PNL Paper 8072, DE92 015994, Pacific North West Laboratory, Richland, Washington US, April 1992.

63 E. Supko, "Integrated Waste Management System Costs in a MPC System", in *Proceedings of HLW Management Conference*, Las Vegas, April 1995, pp 410-414.
Wisconsin PSC, *Final Environmental Impact Statement: Point Beach Nuclear Power Plant Project*, PSC Docket 6630-CE-197, Madison, Wisconsin, August 1994.

64 Calculated with 30% MOX in core of initial enrichment of 7.08% of plutonium.

65 C. Küppers, W. Liebert, M. Sailer, *Realisierbarkeit der Verglasung von Plutonium zusammen mit hochradioaktiven Abfällen sowie der Fertigung von MOX-Lagerstäben zur Direkten Endlagerung als*

could permit to continue operation of the existing MOX facilities, but it was also later calculated that the cost of storage MOX (or "bad MOX") could be up to 30% cheaper and twice as quick to implement as the reprocessing-recycling option for disposal of plutonium[66]. According to the study, the process would allow the treatment of 3.3 to 7 tons of plutonium each year, using only the existing amount of irradiated fuel in Germany. Moreover, the Dutch separated uranium could be used in the fabrication of the storage MOX, solving at least partially this specific problem.

Because the Netherlands will have to face two major management challenges in the coming years, on one hand the spent fuel arising from Borsele's operation after 2004 and on the other hand the separated plutonium stockpile, a consistent solution offering flexibility and a rapid implementation could be the immobilization of the Dutch separated plutonium in storage MOX, stored with Borsele spent uranium fuel in dry storage. Not only this option offers a long-term solution to accompany the shutdown of the sole Dutch nuclear reactor, but also presents satisfactory high standards complying with the tightening international requirements for spent nuclear fuels and separated plutonium management.

Alternativen zum Einsatz von MOX-Brennelementen, Öko-Institut, 1999, 113 pages.
See also Küppers Ch., Liebert W., Sailer M., *Feasibility of Vitrification of Plutonium Together with High Active Waste Concentrate and Fabrication of MOX Storage Rods for Direct Final Disposal* Instead *of a Use of MOX Fuel for Further Handling of Separated Plutonium*, Technical Committee Meeting on "Factors Determining a Long Term Back End Nuclear Fuel Cycle Strategy and Future Nuclear Systems", Vienna, November 1999.

[66] F. Barker, M. Sadnicki, *The Disposition of Civil Plutonium in the UK*, April 2001, 241 p.

Annex 1

Table 3 - Past and present quantities under contract with foreign clients for spent oxide fuel reprocessing at COGEMA La Hague

Contract (1)	**Germany**	**Japan**	**Belgium**	**Switzerland**	**Netherlands**	**Total**
Baseload UP2						
Date	*1972-1989*	*1975*	*1976-1981*	*1975-1981*	*1978-1988*	
Contracted	1,643	151	139	132	85	**2,150**
Reprocessed	1,643	151	139	132	85	**2,150**
Serv. Agr. UP3						
Date	*1978-1990*	*1975-1985*	*1978*	*1978*	*1978*	
Contracted	2,926	2,793	464	516	141	**6,840**
Reprocessed	2,700	2,793	464	469	141	**6,567**
Post Serv. Agr.						
Date	*1990-1996*	-	*1991*	*1997*	*1993*	
Contracted	1,412	-	68	113	157	**1,750**
Reprocessed (2)	127	-	68	18	43	**256**
Total						
Contracted	***5,981***	***2,944***	***671***	***761***	***383***	**10,740**
Reprocessed (2)	***4,470***	***2,944***	***671***	***619***	***269***	**8,973**

(1) Three successive batches of contracts have been signed with foreign clients, respectively:
- "Baseload" contracts in UP2-400;
- "Service agreement" contracts in UP3;
- "Post service agreement" contracts.

(2) Reprocessed quantities are given as of 31 January 2002.

Source: CSPI, April 2002

Annex 2

Table 4 - Synthetic Table of the situation of UE Member States (1) regarding nuclear, reprocessing and MOX programmes

	Nuclear Fleet	Reprocessing	MOX Use
Austria	No Program	No Program	No Program
Belgium	Phase-Out	Finished	Phase-Out (3)
Denmark	No Program	No Program	No Program
Finland	New reactor ordered	No Program	No Program
France	New reactor studied	Going on (2)	Going on (3)
Germany	Phase-Out	Phase-Out	Phase-Out
Greece	No Program	No Program	No Program
Ireland	No Program	No Program	No Program
Italy	Shut Down	No new contract	No Program
Luxembourg	No Program	No Program	No Program
Netherlands	Phase-Out	To be decided	Finished
Portugal	No Program	No Program	No Program
Spain	Moratorium	Finished	No Program
Sweden	Phase-Out	Finished	To be decided
United-Kingdom	No new project	Going on (2)	To be decided (3)

(1) Member States as of 30 April 2004. Those among the 10 new Member States that operate nuclear power plants have no plans to develop reprocessing and re-use of plutonium in MOX fuel.
(2) Country operating reprocessing plant(s).
(3) Country operating MOX fuel fabrication plant(s).

Source: WISE-Paris 2004

Annex 3

The COVRA interim storage site at Vlissingen Oost:

The COVRA (Centrale Organisatie Voor Radioactief Afval), created in December 1982, is a private agency owned by EPZ, GKN (operator of the definitely shutdown Dodewaard reactor) and ECN (the energy research center that operates the Petten High Flux Reactor, HFR) for 30% each and 10% state-owned. It is in charge of designing, implementing and operating a single-site, modular facility destined to the interim storage of all Dutch radioactive waste.

The COVRA site, located at Vlissingen Oost, near the Borssele reactor, comprises four modular types of buildings destined to receipt, treat, condition, and finally store the Dutch radioactive waste arising from different nuclear applications (including reactors operation, radioactive sources, etc.):

- The HABOG bunker, designed to store 70 m^3 of vitrified waste (among other HLW), was commissioned in November 2003, and is destined to receive vitrified high-level waste as well as spent nuclear fuels from the Petten HFR.
- The LOG buildings store the ILW and LLW arising from the reactor operation and diverse nuclear applications since 1992. In December 2000, the 10,000 m^3 of capacity were filled at 70% (7,049 m^3) with around 3,736 m^3 (53% of the total capacity) of reactor's operational waste and 3,313 m^3 of wastes from nuclear applications (research, hospitals, sources). As of the end of 2002, three modules over 16 planned were operational.
- The COG buildings are destined to receive the Technologically-Enhanced Naturally Occurring Radioactive Material (TENORM) arising from the ore processing industry (essentially calcinate from phosphor production). As of the end of 2000, one COG building was operational, but neither its capacity nor its waste inventory was known.
- The VOG buildings are destined to receive the depleted uranium produced by the enrichment processes at the URENCO plant sited at Almelo. The construction of the first of six storage buildings started in 2003. This building should have a capacity of 6,000 tHM (7,036 t of U_3O_8).[67]

The Vlissingen site is destined to operate as an intermediate storage site until 2100, when the Netherlands shall, under the industry's plan, have built a deep geological repository where the wastes will be transferred.

[67] Figures and information of the COVRA installations:
• COVRA web site (www.covra-nv.nl);
• Commision des Communautés Européennes, *Communication et quatrième rapport de la commission sur la situation actuelle et les perspectives de la gestion des déchets radioactifs dans l'Union Européenne*, Brussels, 11 January 1999, 133 p., COM(98)799 final;
• IAEA, *Country Waste Profile Report for Netherlands – Reporting Year:2000*, NEWMDB/IAEA, 2003;
• WISE/NIRS, "Conversion plant projects contracted for U.S. depleted UF6 stockpile", in *Nuclear Monitor*, n°573, 13 September 2002.

Annex 4

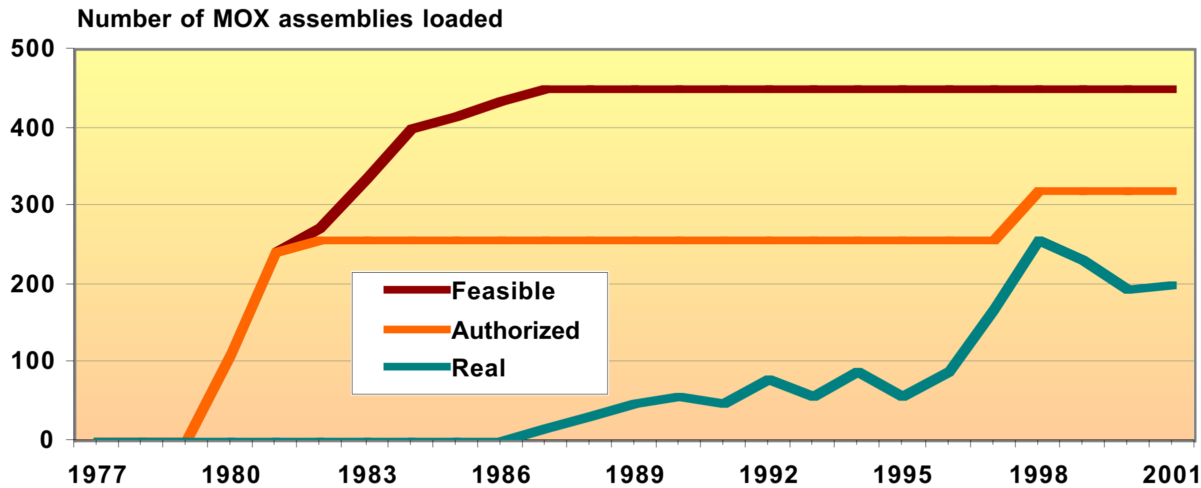
Table 5 - Nuclear materials balances in standard UOX and MOX managements

in kg/TWh	**Standard uranium fuel**	**Uranium and plutonium fuel**
Fuel	100% UOX	30% MOX / 70% UOX
Uranium	-180.0	-157.9
Plutonium	35.6	5.5
Minor actinides	3.4	6.6
Fission products	141.1	145.8

(1) Hypothesis for the fuel management correspond to current practice in French reactors:
- Standard: Kp=75%; UOX only, burn-up=45 GWd/t
- Hybrid: Kp=75%; MOX, burn-up=36 Gwd/t; UOX, burn-up=43 Gwd/t

Source: estimates based on R. Guillaumont, "Gestion des déchets radioactifs", in Techniques de l'Ingénieur*, October 2001*

Figure 3 - Comparison of the number of MOX assemblies loaded in EDF reactors with the authorized and technically feasible limits, 1977-2001



 Source: based on EDF, communication to CNE, Dec. 2000; IPSN, DES n°468, Nov. 2001

Annex 5

Table 6 - Unirradiated plutonium stockpiling by the reprocessing client countries[68]

	1996	1997	1998	1999	2000	2001	2002
Germany	22.5	26.0	26.3	27.7	30.3	26.8	28.9
of which held abroad	*17.6*	*20.0*	*19.7*	*20.5*	*21.2*	*15.9*	*17.8*
Belgium	1.4	0.8	2.7	2.5	1.7	2.1	1.9
of which held abroad	*0.6*	*0.8*	*1.0*	*0.9*	*0.6*	*1.0*	*0.4*
France	35.6	38.7	40.3	43.5	44.2	47	47.9
of which held abroad	*0.2*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
Japan	20.1	24.1	29.3	32.8	37.4	38.0	38.6
of which held abroad	*15.1*	*19.1*	*24.4*	*27.6*	*32.1*	*32.4*	*33.3*
Netherlands	1.3	1.7	1.9	1.9	1.9	2.2	2.4
of which held abroad	*1.3*	*1.7*	*1.9*	*1.9*	*1.9*	*2.2*	*2.4*
Switzerland	0.0	0.7	0.0	0.6	0.6	0.6	0.8
of which held abroad	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*
United Kingdom	51.9	54.9	59.8	61.6	62.4	66.2	70.8
of which held abroad	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*	*0.9*
∑ of national stocks	132.5	146.6	160.0	170.2	178.1	182.4	190.7
of which held abroad	*35.7*	*42.5*	*47.9*	*51.8*	*56.7*	*52.4*	*54.8*

Source: IAEA Information Circulars n°549, 1997-2003 ; WISE-Paris 2004

[68] Because of lacks of information in some declarations, some figures have been estimated:
- Belgium: plutonium in course of manufacturing deducted of the Belgian part (based on figures of the Dessel MOX plant annual productions) is considered as plutonium belonging to foreign bodies (and therefore not counted in the national total);
- Netherlands: figures estimated on the annual progression of spent fuel reprocessed at La Hague and Sellafield; in the absence of any information on the share of Dutch plutonium used for fabrication of Superphénix fuel that was in the irradiated one of the two cores fabricated, the corresponding quantity could not be discounted;
- Germany: plutonium held abroad is deducted from the whole declarations and estimations above and added to the German annual declarations (which avoid to mention the plutonium held abroad).

Annex 6

Radioactive waste arising from reprocessing of uranium oxide spent fuel at the COGEMA plants of La Hague:

High Level Waste (HLW):

- This waste contains mainly the ultimate residues after the extraction of the uranium and plutonium, which are however still present in the solution in low quantities together with the fission products and actinides. The solution is firstly calcinated to operate a reduction of volume before being directed toward the vitrification lines. These lines are designed to produce 25 kg of glass per hour (or 1 canister every 16 hours), melted at a temperature of around 1,150°C. The mix of melted glass and calcinate is poured into 0.18 m^3 stainless steel containers (called universal canisters) at a global rate of 0.13 m^3 of vitrified waste produced per ton of spent fuel reprocessed.

Intermediate Level Waste (ILW):

- The fuel structures that cannot be dissolved during the reprocessing are rinsed, compacted and grouted. The production rate of cemented hulls and nozzles per ton of spent fuel reprocessed (poured into 1.5 m^3 steel drums) has been nearing 0.5 m^3 until 2001. Since the end of 2001, a new workshop named ACC went into operation with a rate of structural wastes production divided by 4 according to COGEMA's information, or 0.13 m^3/t reprocessed thanks to higher compaction rates (poured into 0.18 m^3 canisters comparable to those used for the vitrified waste).
- Until at least 1995, reprocessing activities at La Hague produced also another category of ILW, called bituminized waste (poured into 0.21 m^3 steel drums[69]), in accordance with the bituminization process of the precipitation sludges (formed by the precipitation of fines in the dissolution tanks). The bituminized wastes production rate is unclear but shall roughly meet the figure of 0.4 m^3/t reprocessed. Since 1995, filtration processes and new effluents management conducted to split the radioactive flow until then dedicated to bituminization, part of it released in the liquid and gaseous effluents and part redirected to the vitrification line.

Low Level Waste (LLW):

- Regarding the LLW production, two major types of wastes can be distinguished: long-lived alpha contaminated wastes and short-lived wastes. These technological wastes arising from the contamination of equipments used during the reprocessing processes are compacted and grouted into 1.18 m^3 fiber concrete containers called CBFC (category 1 for the short-lived and category 2 for long-lived LLW). The technological wastes production rates largely decreased with time, and especially since 1995 for the short-lived category. According to COGEMA's figures the long-lived technological wastes production rate should currently reach 0.35 m^3/t reprocessed, and 1.4 m^3/t for the short-lived one (at least 1.6 m^3/t before 1995).[70]

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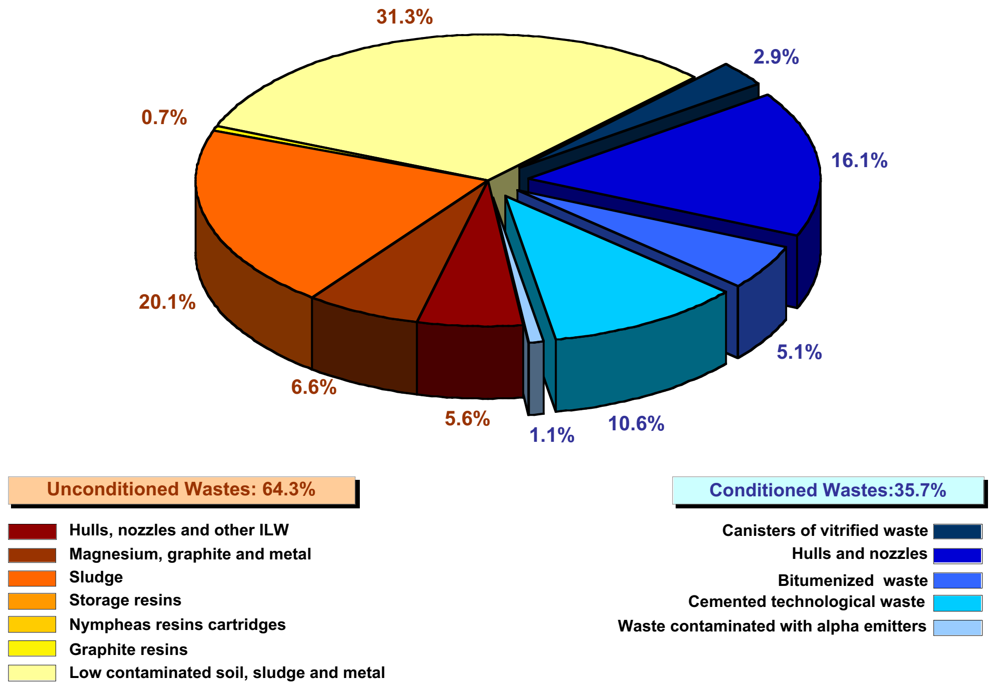
[69] COGEMA, *Spécification des déchets bitumés produits dans ST3B*, Seconde série, February 1991.

[70] Figures for waste production rates come mainly from:
P. Pradel, P. Fournier, P. Miquel, et *al.*, "Waste Minimization and Management Along Processing and Recycling of Nuclear Materials", COGEMA, in *WM'98 – Waste Management, Proceedings of the March 1-5, 1998 Conference*, Tucson, Arizona, United States, 6 p.

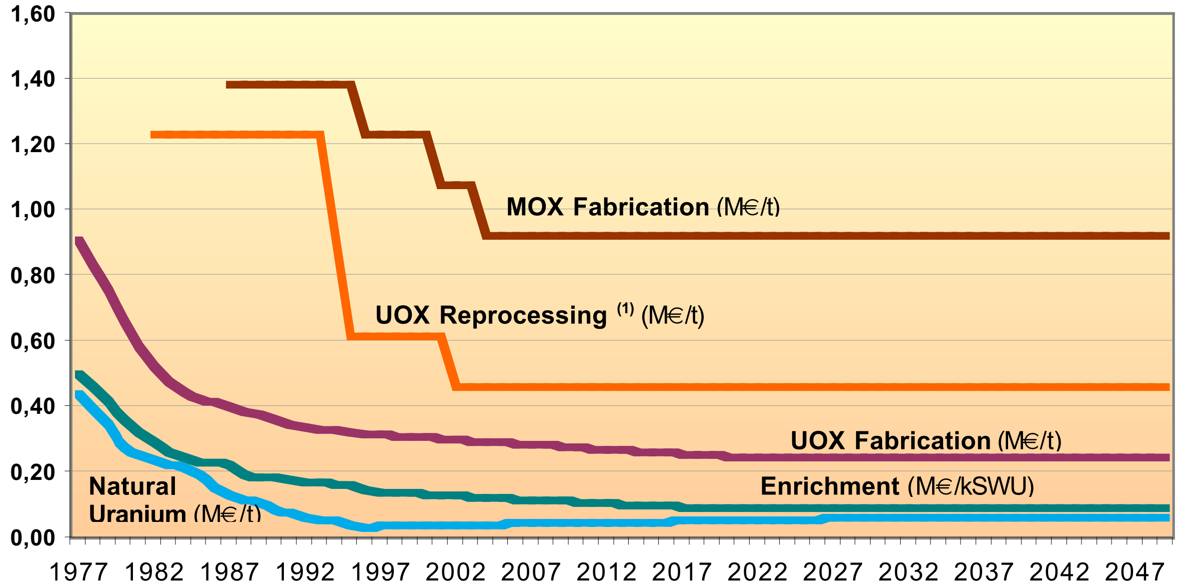
Figure 4 - Conditioned and unconditioned wastes at La Hague as of 31 December 1999 (in % of total volume)



Source: WISE-Paris, based on ANDRA, National Inventory of Radioactive Wastes*, 2000*

Annex 7

Figure 5 - The costs of the fuel cycle in the "Charpin-Dessus-Pellat" report: past and projected unit costs for the fuel fabrication and reprocessing



(1) From the start-up of UP2-800 in La Hague in 1994, the cost of reprocessing is separated in investment cost and operation cost: only the second one appears on this figure. The investment cost of UP2-800 is assumed to amount to €6 billion (1999 value), plus €2 billion (1999 value) for the decommissioning of the plant, and €1.5 billion for upgrading at the half-life of the plant. Also assuming that the total cost for one year of operation of the plant is €0.6 billion (of which 80% are fixed cost and only 20% proportional to the quantities reprocessed), one can calculate the total average reprocessing cost for UOX fuel under various hypothesis, for instance:

- 1.1 M€/ton for a 30 years lifetime and 800 t/year;
- 1.02 M€/ton for a 40 years lifetime and 800 t/year;
- 1.2 M€/ton for a 30 years lifetime and 700 t/year;
- 1.01 M€/ton for a 30 years lifetime and 900 t/year.

Source: WISE-Paris, based on Girard, Ph. & Marignac, Y., 2000

Table 7 - The costs of the fuel cycle in the "Charpin-Dessus-Pellat" report: unit costs for interim storage and final disposal of fuel cycle waste

Operation	Cost	per unit
Direct disposal of reprocessing waste		
Final disposal of ILW	0,07	M€/m^3
Final disposal of HLW (vitrified waste)	0,14	M€/container
	(or 0,64	M€/m^3)
Direct disposal of spent fuel		
Interim storage of spent UOX fuel (50 years)	0,15	M€/ton
Interim storage of spent MOX fuel (150 years)	0,38	M€/ton
Final disposal of spent UOX fuel	0,29	M€/ton
Final disposal of spent MOX fuel	1,22	M€/ton

Source: WISE-Paris, based on Girard, Ph. & Marignac, Y., 2000

Table 8 - Material balances and economic comparison of various options for the fuel cycle of the French nuclear power plants

Scenarios[1] *(ref. in Report)* **Reprocessing**	***S4*** **Stops in 2010**	***S5*** **Partial**	***S6*** **Total**	***S7***[2] **None**
Generated electricity (TWh)	20,238	20,238	20,238	20,238
Material balances				
Natural uranium (kt)	460	447	437	475
Reprocessed UOX (kt)	15.0	26.2	36.1	0.0
Separated Pu re-used (t)	146	275	387	0
Irradiated UOX (kt)	41.0	28.6	17.6	58.3
Irradiated MOX (kt)	2.0	3.5	4.8	0.0
Pu content [3] (t)	602	555	514	667
Interm. Level Waste (m^3)	31,786	34,825	38,091	20,000
from operation	*20,000*	*20,000*	*20,000*	*20,000*
from reprocessing	*11,786*	*14,825*	*18,091*	*0*
High Level Waste (m^3)	1,601	3,325	4,808	0
Economics of the nuclear fleet				
Global cost (G€)	**440**	**444**	**446**	**421**
• Investment	104	104	104	99 [4]
• Operation	198	198	198	198
• Total of fuel cycle	139	142	145	124
Cycle front end	*92*	*90*	*88*	*93*
Cycle back end	*30*	*35*	*40*	*13*
End of cycle	*17*	*17*	*16*	*16*
Cost per MWh [5] **(€)**	**21.75**	**21.92**	**22.04**	**20.81**
Detail of fuel cycle costs (G€)				
Front-end 1977-1998	41	41	41	41
Front-end 1999-2049	50	49	47	52
Total Front-end	***91***	***90***	***88***	***93***
Back-end 1977-1998	14	14	14	0
Back-end 1999-2049	16	21	26	13
Final disposal ILW+HLW	2	3	4	0
Final disposal spent fuel	14	13	11	17
Total Back-end[6]	***46***	***51***	***55***	***30***
Total Fuel Cycle	**137**	**141**	**143**	**123**

(1) All scenarios based on the hypothesis of an average 45 years lifetime for the nuclear reactors.
(2) Retrospective scenario corresponding to the same operation of the current nuclear power plants without any reprocessing, even in the past period (1977-2000).
(3) Plutonium content (plus Americium that it forms) in UOX and MOX irradiated fuel that are not reprocessed at the end of the period (when the last reactor shuts down).
(4) The difference in investment costs between the scenarios with reprocessing (S4, S5, S6) and the one without is due to the cut of 4,6 G€ of R&D costs for the fuel back-end.
(5) Non discounted levelized costs estimated from global cost over the producing life of the power plants, calculated on a constant € value (year 1999).
(6) The "back-end" lines include the interim storage of final waste, and the "final disposal" includes that of MLW and HLW from reprocessing (not from reactors operation) and of non reprocessed spent UOX and MOX.

Source: WISE-Paris, based on Girard, Ph. & Marignac, Y., 2000