COULD WEAPON-GRADE PLUTONIUM BE AN ASSET FOR MANAGING PU INVENTORIES?

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Abstract

Due to the temporary shortage of MOX fuel fabrication facilities, the stockpile of separated civilian grade Pu (CPu) is predicted to increase up to the turn of the century. An additional quantity of weapon grade Pu (WPu) will be progressively isolated at the same period. Both CPu and WPu surplusses require disposition as soon as feasible.

Although non-proliferation concerns, established national policies, public acceptance problems and other considerations largely complicate the aspect of the use of WPu, it is worth examining the advantages which could result from a synergetic management of :

- LWR grade Pu to which AGR grade Pu might be associated
- WPu
- GCR grade Pu which should be considered as a Pu variety situated between the two first ones as far as their physical and neutronic characteristics are concerned.

Two scenarios of integrated managements of the CPu varieties and WPu are being considered. They indicate several technical and economical advantages but also important problems to be resolved, mainly from the non-proliferation point of view. In that respect, it is concluded that, although no reasonable perspective exists to resolve these problems easily (or at all), the advantages justify an effort of the international community to consider how it could be implemented.

1. INTRODUCTION

Disposition of separated Pu has attracted wide attention from political authorities, mainly in the perspective of non-proliferation and safeguard concerns. A lot of alternatives are being considered :

- utilization as MOX(1) fuel in LWRs, FNRs and ATRs using commercially established technologies;
- utilization in CANDUs and HTRs, being studied in conceptual projects based on earlier R & D results;
- unconventional options based either on existing power plants (LWRs, FNRs and CANDUs), on power plants developped earlier (HTRs and MSRs) or on new concepts based on accelerator-driven sub-critical reactors;
- ultimate disposal after conditioning for insolubilisation and diversion resistance.

(1) : A list of abbreviations and acronyms is given in the Appendix

Emphasis in this paper will be on the first alternative, since it leads to the earliest possible disposition of separated Pu inventories. Indeed, MOX is being or has been utilized, at commercial scales, in 6 of the 30 countries operating nuclear reactors, representing 41% of the installed nuclear capacity in the world. Additionally 7 other countries, totalling a further 44% of the installed capacity, have conducted demonstration irradiations of MOX fuel.

More details on the assumptions and considerations underlying this presentation are contained in [1].

2. COMPARISON OF Pu UTILIZATION ALTERNATIVES

Table I provides the disposition capacity over the next 10 and 20 years using each reactor type, if all the reactors of that type were loaded with a maximum of Pu fuel, for two installed capacity assumptions :

- the reactors connected to the grid and under construction;
- the same plus 10 GWe;

Table I. Pu UTILIZATION CAPACITY (t Put) OF EACH POWER REACTOR TYPE

Installed generating capacity considered	current + under construction		same + 10 GWe	
Period	10 yr	20 yr	10 yr	20 yr
LWR				
current MOX (33%)	3300-4400	9000-10000	3300-4400	9000-10000
100% MOX core	3300-4400	17000-20000	3300-3400	17000-20000
alternative Pu fuel	0	0-7000	0	0-7000
CANDU				
MOX fuel	28-80	170-230	70-200	400-540
alternative Pu fuel	0	0-410	0	0-580
FNR	14-43	90-120	50-150	300-400
ATR	2	13	2	13-110
HTR	-	-	0	negl

The ranges reflect the ranges assumed for disposition rate in each system and for lead times before industrial utilization.

It shows that MOX utilization in LWRs is the most expeditious solution to eliminate Pu stockpiles, as already concluded in [2]. The calculations indicate that, even if only 10% of the LWRs were loaded with MOX fuel, as currently applied (i.e. MOX fuel constituting one third of each reload), an inventory of 200 t Pu could be utilized within 6 to 8 years and an inventory of 400 t Pu within 9 to 11 yrs. It justifies to consider only the MOX in LWRs alternative in this paper of limited scope.

This does not prejudice recognition that alternative systems have intrinsic advantages and that, Pu not being a fungible commodity, national context may influence the choice of the Pu disposition scenario(s).

3. Pu INVENTORY

3.1. Status at end 1994

As a result of studies conducted by FEX [3] and of data published by Japan AEC [4], the separated CPu inventory at end 1994 can reasonably be evaluated at :

- 120 t Put stored as raw material, in good agreement with the 112 t Put predicted [5] by a model developped by the IAEA [6], taking into account the simplifying assumption adopted in both assessments;

- 12 t Put stored as MOX and Pu bearing experimental material.

3.2. Future arisings

When THORP will reach steady state operation, a total of 29 t Put will be separated per year. When Rokkasho-mura will be in operation (i.e. after 2004), the arisings will go up to 38 t Put per year.

To these quantities of CPu should be added the WPu which will be available as a result of the START agreements and can be considered now as stored in the form of low-alloyed Pu metal. In general, publications indicate rounded figures of 100 t Pu from the Russian arsenal and 50 t Pu from the American arsenal which should be separated from warheads within the START commitments.

The so calculated arisings (Fig.1) should be considered upper boundary, since it is based on the current La Hague, Sellafield, Tokai-mura and Mayak reprocessing plants operating at rated capacity and on the future Rokkasho-mura and Krasnoyarsk reprocessing plants to be on schedule. Given the cancellation of post-baseload committments by German utilities, the schedule shifts observed in startup of new reprocessing plants and the reduced capacity factor usually experienced during the first years of operation of novel plants, the actual Pu arisings might be significantly lower.

3.3. Availability of recipient reactors

Although the quantities look large, Table I indicates that disposition of 750 t Put over 15 years can be achieved by loading

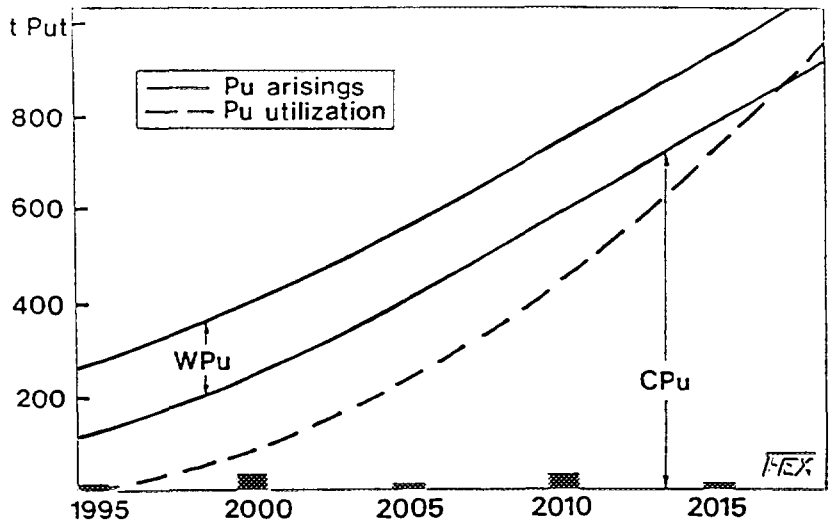

Fig. 1. Cumulated Pu arisings and utilization since end 1994

MOX fuel in all existing and today foreseen FNRs and ATRs and 7 to 10% (23 to 32 GWe) of the LWRs (1/3 MOX reloads). Since 43% of the LWR capacity is installed in countries possessing commercial experience of MOX fuel utilization, only 6 to 23% of the LWRs in those countries would need to be loaded with MOX fuel to reduce the stockpile to zero by 2010. Currently, there are 34 reactors licensed to use MOX fuel and 25 others in the licensing process, representing a total of 54 GWe. Furthermore, other reactors, such as CANDUs, and advanced systems, such as 100% MOX cores in LWRs, offer interesting perspectives for Pu utilization and will probably also contribute to Pu disposition, thereby reducing the number of LWRs to be loaded with MOX fuel.

It can be concluded that availability of reactors is, in principle, not the limiting factor for Pu disposition.

4. MOX FABRICATION

4.1. Fabrication capacity

Table II provides an indicative overview [4,5,7,8,9,10] of the existing and planned MOX fabrication capacity available for LWR, ATR and FNR fuel. It should also be considered upper boundaries. Due to the large investment required and the decommissioning fund to be constituted, implementation of any additional MOX fabrication facility requires assurance that operation at, or close to, rated capacity is possible over a long period of time. The fate of the Hanau MOX plants has not provided industry with confidence in that respect.

4.2. Pu processing capacities

Based on Table II, the existing fabrication capacity is able to fuel 12 GWe of FNRs. This is much more than the 4.1 GWe in operation and under construction, of which a total of 1.7 GWe in France, Japan and 2.4 GWe in Kazakhstan and Russia. For BN 800 FNRs

Table II. MOX Fabrication capacity (tHM/yr)

FUEL	1995	2000	2005
LWR	100	300	410
ATR	10	40	50
FNR	21	22	80

in Russia, no definite planning has been communicated; nevertheless, two first BN 800s have been included in the above figures. Anyway, the contribution to disposition of the Pu stockpile is relatively minor.

In PWR fuels [11,12], the Pu content varies presently between 4.2 and 6.0% Put FA average, with a representative value of 5.3% Put. In the future, MOX discharge burnup will be increased from the current 36 GWd/t to the planned 41-45 GWd/t, a design basis already implemented for the MOX fuel loaded in 1995 in the Belgian PWRs [13]; the Pu content will then rise to a representative value of 6.4% Put. In the next century, when target burnup will increase further and the available CPu from reprocessing LWR fuels will have a fissile content of 62-65% instead of the current 70%, the average Pu content of MOX will reach 7 to 9% Pu t [11,12,13,14].

BWR MOX fuel is now designed for discharge burnups similar to PWR fuel and the average Pu contents range from 4.2 to 8% Put [15,16], depending mainly on the FA design.

Based on these considerations and on Table II, the LWR MOX fabrication plants, which have processed 20 t Put before end 1994, will use as fuel in the future :

- 70 t Put in the period 1995-2000;
- 140 t Put in the period 2001-2005;
- 160 t Put in the period 2006-2010.

ATR fuel production is not limited by fabrication capacity but by NPP fuelling requirements.

4.3. Evolution of the Pu stockpile

Figure 1 provides an overview of the Pu arisings and utilization resulting from the assumptions outlined in Sections 3 and 4. The Pu stockpile should reach its maximum shortly after the year 2000 and should be eliminated by 2017 if only CPu is being utilized and shortly after 2020 if WPu is also utilized.

These conclusions are only valid if Pu obligations and ownership liabilities do not prevent fabrication capacities and MOX fuelling opportunities to be adequately utilized. Since fabrication capacity is the bottleneck for many years to come and fabrication for foreign customers is a commercially established practice, it is unlikely that institutional obligations or regulations will have a major influence in restricting Pu disposition.

However, most MOX manufacturing plants are not designed and/or licensed to use Pu of isotopic composition corresponding to WPu. Some plants are not even provided with a cross-blending step of the feed powders, which thus enables to homogenize Pu feeds of different origins. This complicates the logistics of Pu disposition, but will probably not influence its disposition rate.

The assumed rate of Pu disposition depends on the fabrication capacity assumptions and on the MOX discharge burnup targets, but the prospect of Pu stockpile exhaustion is not much affected. If a 40 tHM/yr additional LWR fuel fabrication capacity starts commercial operation in the year 2000, the exhaustion of the Pu stockpile would take place one to two years earlier. If extended burnup of MOX fuel were implemented 4 years earlier than assumed, the exhaustion of the stockpile would take place one year earlier.

5. Pu CHARACTERISTICS

5.1. Types of Pu

While WPu is relatively uniform in isotopic composition, CPu has a large variety of compositions depending on the reactor in which it was generated and the burnup of the spent fuel it was reprocessed from (Table III). The cumulated quantities of each type of Pu can be estimated (Fig.2) with a fair accuracy. The disposition requirements will be dominated by LWR Pu up to the year 2000, because WPu will not yet be available in significant quantities and thereafter because reprocessing of spent LWR fuel will largely exceed the other Pu arisings.

Isotopic composition has an impact on Pu storage, MOX fabrication and MOX utilization in NPPs.

5.2. Radioactivity

The alpha activity of Pu comes mainly from Pu 238 and Am 241. The heat generation resulting therefrom is a limiting feature for Pu storage as well as for MOX fabrication, storage and transportation.

The gamma activity of Pu consists essentially in the high energy low intensity gammas from the Pu 236 daughter products, the medium energy high intensity gammas from U 237 (resulting from alpha decay of Pu 241) and the low energy high intensity gammas from Am 241. The activity increases with aging : the differences

Table III. REPRESENTATIVE ISOTOPIC COMPOSITION OF Pu (rounded %)

Pu type NPP GWd/t	Pu 238	Pu 239	Pu 240	Pu 241 + Am 241	Pu 242
WPu	0.0	94	5.5	0.5	0.0
GCR 5-6	0.2	69	25	4.9	1.2
AGR 18-24	0.6	54	31	10	5
PWR 33-35	1.6	58	25	10	5.5
43	2.6	56	24	12	6.3
52	2.7	50	28	11	8
BWR 30	2.8	55	23	14	5

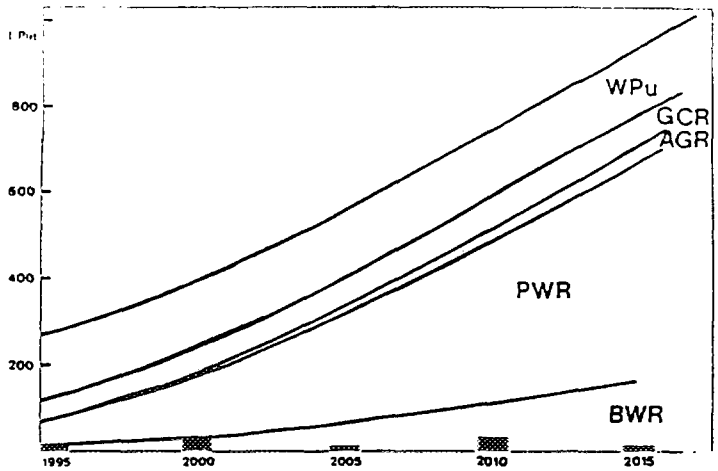

Fig.2. Cumulated Pu quantities requiring disposition

between Pu types after 5 or 10 years ageing is important (Table IV). The gamma activity impacts fuel fabrication, transportation and handling at the reactor site.

The neutron activity of Pu results from spontaneous fissions and from alpha-n reactions in the oxide. Pu 238, Pu 240, Am 241 and Pu 242 are the emitters, with a moderate increase of neutron activity after 5 yr aging for LWR Pu. This radioactivity is very difficult to shield and results in considerable detriment for fuel fabrication, storage, transportation and handling at the reactor site.

Table IV. RELATIVE GAMMA DOSE RATES OF THE DIFFERENT TYPES OF Pu AFTER 5 AND 10 YEAR AGING

Type	WPu	GCR	AGR	PWR	BWR
5 yr	1.0	4.9	9	11	12
10 yr	1.3	8	13	17	20

As concerns radioactivity, WPu and GCR Pu are gentle materials to process and utilize, compared to the other CPus and especially if aging is to be taken into account as the result of temporary imbalance between Pu arising and MOX fabrication capacity.

5.3. Nuclear characteristics [17]

Although all Pu isotopes and Am are fissile in fast neutron fluxes, only Pu 239 and Pu 241 have significant fission cross-sections within the neutron spectrum typical of LWRs. The relative reactivity lifetime value of the various isotopes (if 1.0 is attributed to Pu 239, typically : -0.18 for Pu 238, -0.3 for Pu 240, +1.2 for Pu 241, -1.7 for Pu 242 and -1.8 for Am 241) leads to requiring higher Pu contents for MOX fuel with LWR Pu than with WPu or GCR Pu. The harder neutron spectrum resulting therefrom reduces

the boric acid and control rod worths. Moreover, the quality of LWR Pu is very susceptible to aging : after 10 years storage (as PuO_2 feed material and/or MOX fuel) WPu has lost 1% of its reactivity value, CGR Pu 7%, current PWR Pu 24% and PWR Pu from high burnup spent fuel 31%. The Pu contents of MOX fuel must further be increased accordingly.

The reactivity evolution with burnup, which is much flatter for MOX than for UOX fuel, is only slightly better with WPu and CGR Pu than with LWR Pu. It does not constitute a distinct advantage for any Pu type. Similarly, the 1% higher fission energy of Pu 241 than the Pu 239 can be overlooked.

The interplay of the various Pu isotopes with high absorption resonances in the epithermal energy range (5 000 barns at 0.3 eV for Pu 239, 100 000 barns at 1 eV for Pu 240 and 2 000 barns at 0.26 eV for Pu 241) constitutes a challenge for the calculational methods. In this respect, MOX fuels fabricated from WPu or GCR Pu are much easier to design and license than MOX fuels from LWR or AGR Pu. However, larger inventories of Pu isotopes shift MOX moderator temperature and fuel temperature (Doppler) coefficients to more negative values. The latter is instrumental in early termination of RIAs (e.g. CR ejection in PWRs and CR drop in BWRs); given the attention devoted recently to RIA licensing limitations, LWR and AGR Pu have a definite advantage over WPu. A higher moderator temperature coefficient is a mixed blessing : it improves core stability and stretch-out operation capability, but renders the core more susceptible to accidents involving injection of cold water in the core (e.g. steam-line break in PWRs and turbine trip in BWRs). MOX fuel with high Pu contents and especially high Pu 240 content (such as high burnup MOX fuel fabricated from aged AGR Pu) may exhibit positive void coefficients [18], thus raising new licensing issues. The fraction of delayed neutrons, 0.0022 for Pu 239 and 0.0054 for Pu 241 (close to U 235, also for delayed neutron half-lives), provides for a better control and safety behaviour to MOX from LWR Pu than from WPu.

This glimpse of nuclear design and licensing features reveals pros and cons for each type of Pu feed. A global assessment is that WPu is simpler to manage and therefore better suited for less experienced teams while, on the other extreme, LWR Pu is more sophisticated to design for, but provides improved operational behaviour and licensing margins (unless these are eroded by design uncertainty margins). However, aging deteriorates rapidly the assets of LWR and AGR Pu.

5.4. Spent MOX fuel

During reactor operation, the radioactivity inventory of MOX fuels, at the same power and burnup, is dominated by the fission products. The differences in fission yields between Pu 239 and Pu 241 are small. In accident conditions and for short times after shutdown and unloading, the radioactivity of MOX fuel is almost unaffected by the type of Pu utilized. For interim storage, spent fuel transportation, reprocessing and high level waste (or spent fuel) disposal, the Pu type from which the MOX was fabricated plays an important role, due to the different inventories [19,20] of Pu 238 (which dominates radiotoxicity the first 10-20 years after discharge), Am 241 (which dominates thereafter up to 1 000 years), Cm 244 and Pu 241 (both of which fade out 100 years after discharge). Consequently, for what concerns spent fuel management, WPu is the most gentle type to utilize and LWR Pu is the worst.

6. EXTERNALITIES

The choice of a Pu management scheme cannot be based only on technical, safety and economic considerations, as was the case in the 1960s and 1970s, when Pu was considered primarily as a resource and, hence, as a tradable good. Progressively, non-proliferation, national policy and public acceptability implications have emerged as prime concerns : this resulted in widespread impediments to the free flow of all nuclear goods and services, but particularly Pu. Emphasis shifted from considering it as a resource to booking it as a liability with obligations attached to it and quite a large uncertainty about the future evolution of regulations. Practically, due to the absence of a Pu market, each Pu owner is now forced to care for the disposition of his own Pu in his own system.

For LWR Pu, commercial utilization of MOX started in the mid-1970s and, mainly from the 1980s, expands continuously. Nevertheless, postponement or cancellation of the FBR industrial programmes together with shortage of LWR MOX manufacturing capacity are the main causes of the increase of LWR Pu stockpiles up to the early 2000s. The resulting deterioration of the Pu isotopic composition will degrade MOX fuel fabrication and utilization conditions and might necessitate very expensive Am separation.

AGR Pu starts arising this year, since the operation of THORP has begun. It is also a Pu type with unfavourable aging characteristics. Although MOX was loaded, on a small demonstration level, in WAGR during the 1960s and performed well and notwithstanding the favourable nuclear and safety attributes of graphite moderated cores loaded with MOX fuel, neither the GCR NPPs nor the AGR NPPs can contribute to Pu disposition. The AGR FA design and the fuel route at NPPs for defuelling-refuelling renders adaptation to MOX fuel impracticable. The GCR fuel is metallic with magnox cladding : the manufacturing infrastructure is not available for Pu fuel and compatibility of magnox with metallic Pu fuel is, at best, questionable. In principle, oxide fuel in AGR type cladding can serve as design basis for alternative GCR fuel, but the time required to demonstrate the new fuel design, first with enriched U, then with MOX demo FAs, would shift the start of commercial implementation to ten years from now, i.e. too late, since all CGR stations still in operation are scheduled to close successively in the period 2001-2006 [21]. Only the unique PWR plant operating in the UK and contemplated future PWRs (unlikely to start operation before 2002 and be receptive to MOX fuel before 2004) can provide for the disposition of the accumulating UK stockpile.

GCR Pu has historically been utilized in FNRs, but a large stock has been left unused and will continue to increase (Fig.2) as long as GCRs continue operation. Since GCR Pu deteriorates at a reduced rate with aging, disposition is not a matter of urgency. Nevertheless, for economical (cost of Pu storage) and political reasons, the GCR Pu cannot remain stored for many further decades. It represents, in Europe today, close to 50% of the stockpiled separated Pu.

WPu practically does not deteriorate with aging and, in that respect, long term storage would not be a problem. But leaving military stockpiles neatly stored, ready to be incorporated on short notice in even more efficient warheads than the ones they were recuperated from, is not in the spirit of START. Disposition of WPu, or at least early denaturation to non-weapon Pu quality, is therefore a matter of urgency. The dismantling of warheads and

transformation of low-alloyed Pu metal to PuO_2 in yet non-existent facilities of adequate capacity, results, unfortunately, in WPu not being available for incorporation in MOX fuel before the turn of the century. Furthermore, acute safeguard concerns and feelings that WPu is a national treasure will incline the concerned countries (Russia and USA) to a policy of processing their WPu only in national facilities, at least to a point where WPu is denaturated, e.g. by blending with CPu; but only Russia has and continues to produce separated CPu. It is obvious that no one of these two countries will denaturate its WPu, unless the other country does the same at the same rate. Therefore, availability of WPu to fuel NPPs may even be delayed further. Finally, public acceptance may even be more of a problem for MOX made from WPu and this should not be overlooked.

In short, at the start of next century, most of the Pu utilized by then (Fig. 1) will be LWR Pu and the other Pu types (Fig. 2) will still be stockpiled, half of it being WPu, 30% LWR Pu, 20% GCR Pu and some % AGR Pu.

Notwithstanding severe regulations (a.o. obligations resulting from prior consent rights), flexibility of Pu management has been achieved : the administrative paperwork, safeguard precautions and commercial conditions to allow fungibility between CPu lots, even if present at separate locations, have been developped and implemented. Pu owners and MOX manufacturers are routinely taking advantage of this fungibility to improve Pu management. For the reasons explained before, extension of fungibility to WPu will require determination, innovation and time.

Restrictive regulations have increased the transportation cost of Pu and MOX and administrative restrictions or public acceptance problems have resulted sometimes in unscheduled delays. But, altogether, movability of Pu and MOX is being maintained. Transportation of WPu has also taken place on a large scale in military conditions, but will need to be reorganized into civilian practices.

In summary, there is an imbalance between the arisings and the rate or even the possibility of utilization of each Pu type in isolation. Management of CPu has been resolved by fungibility practices. The obstacles to eliminate for extending fungibility to WPu are important. Only if the incentive to manage rationally CPu and WPu together is important, would it be worthwhile to tackle the problems and seek for solutions.

7. INCENTIVE TO INTRODUCE WPu IN A GLOBAL Pu MANAGEMENT PLAN

Am 241 buildup has emerged as a measure or indicator of the inconvenience of Pu aging. Attention has been focussed so much on this indicator that projects are being launched to purify aged Pu by stripping Am. It reduces part of the radioactivity of aged Pu, but exclusively in the soft energy range, which is only a problem in the MOX fabrication plant and a minor problem in the future, as most recent plants are designed to handle Pu with 3% [22] or even 4% [23] Am 241 contents. Purification also restores part of the reactivity loss due to aging. However, it is costly and the economics of MOX fuel are already the subject of severe criticism. Additionally, the separated Am constitutes an additional HLW stream and a particularly noxious one since, as mentioned in Section 5.4., Am dominates radiotoxicity of spent fuel from 10 to 1000 years after reactor discharge. It could be argued that R & D programmes

are being pursued to transmute minor actinides : as long as those programmes have not produced conclusive results and industrial implementation is not guaranteed, Am would better be left in the Pu and irradiated in the MOX fuel, than shelved for an uncertain future at unknown additional cost.

Although a complete analysis would be necessary, this presentation will, for simplicity's sake, utilize the standard "Am content" measurement stick to glance at potential advantages of a globalized management of all Pu stocks. Moreover, only two scenarios will be illustrated : separate utilization of each Pu type and blending some CPu with WPu.

The first scenario assumes that blending CPu and WPu is not possible and that LWR Pu would be utilized first, then AGR Pu, thereafter GCR Pu and, finally, WPu. The average age and Am content of each Pu type is calculated at the most critical time at which it is processed (Table V), namely in the early 2000s for LWR Pu, when fabrication capacity should start to reduce the separated Pu inventory, and in the early 2010s for AGR Pu, when the UK Pu inventory can be utilized at industrial scale in national NPPs (either new PWRs replacing the shut down GCRs, or prolonged life GCRs with redesigned fuel concept). In this scenario, WPu disposition would take place in the late 2010s and an interim storage of important quantities of WPu in metallic or, even better, in oxide form will have to be undertaken. This constitutes a real weak aspect of the unavoidable interim storage of WPu [24]. In that respect, mixing WPu with CPu is favourable for the non-proliferation aspect, since it complicates plutonium diversion (quantities are bigger, radioactivity is higher).

In the second scenario, the WPu is supposed to become available for processing into MOX in the early 2000s and to be blended in a 1/1 proportion to CPu, to both denaturate the WPu as soon as possible and to cope with the aging of the most critical batches of CPu. Table V illustrates that this notional scenario improves the aging situation over scenario 1. It shows that coordinated management of the global Pu stockpile (or free-trade type fungibility of Pu amongst owners) is capable of providing for a more efficient and safe management of the Pu arisings.

Table V. AVERAGE AGE AND Am CONTENT OF Pu STOCKS AT THE MOST CRITICAL TIME FOR MOX FABRICATION AND UTILIZATION

Scenario	1		2	
Pu type	Age(yr)	% Am	Age(yr)	% Am
WPu	50-60	0.4-0.5		
GCR	34-40	3.9-4.2	35-40	2.2-2.3
AGR	14-15	4.9-5.1	17-18	3.0-3.1
PWR	5-8	2.1-3.2	9-12	2.0-2.4
BWR	5-8	3.0-4.5	9-12	2.7-3.3

Scenario 1 assumes that each Pu stock is undiluted with other Pu types and utilized sequentially.

Scenario 2 assumes that WPu becomes available soon after 2000 and, while stock lasts, it is blended to CPu in a 1/1 ratio, i.e. 50% CPu-50%WPu.

In the real world, all the Pu batches will not be of the average quality of CPu types illustrated in this presentation; some will be worse. The actual individual and national context of each Pu owner will prevail in the constraints he faces and the flexibility he has to manage his Pu arisings. Reluctance and problems to insert WPu in the civilian utilization of MOX are the major obstacles to optimize disposition of the Pu arisings. The difficulties should not be a reason to prejudge that adequate solutions cannot be found : the economic, environmental and safety benefits are large enough to try, even if full success is still not certain.

8. CONCLUSION

The temporary imbalance between CPu arisings and MOX fabrication capacities will result in separated Pu stockpiles building up until the first decade of the 2000s and then progressively being exhausted. During this interim period, the aging of CPu deteriorates the manufacturing and utilization conditions of MOX fuel. The inventory of separated Pu requiring disposition will increase by the WPu obtained from dismantling of warheads. While it prolongs the period before exhaustion of the separated Pu stockpile, a coordinated management of the CPu and WPu would result in big advantages on disposition of Pu stockpiles by accelerating denaturation of WPu and by improving fabrication and utilization of MOX fuel.

Institutional policies, public acceptability problems, safeguard concerns and stalling of progress on WPu disposition prevent the Pu stocks from being processed and utilized in the most economic and safe manner. The international organizations (IAEA, OECD, NATO, EC) can help resolve the issues by organizing working groups, conducting studies, publishing popularization and technical documentation and promoting coherence amongst the member states.

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APPENDIX : ABBREVIATIONS AND ACRONYMS

AEC : Atomic Energy Commission
AGR : Advanced GCR
ATR : Advanced Thermal Reactor : heavy water moderated, light water cooled calandria type (Japan)
CANDU : Pressurized Heavy Water Reactor (Canada)
CPu : Civilian grade Pu
CR : Control Rod
EC : European Commission
FA : Fuel Assembly
FEX : Nuclear Fuel Experts, sa
FNR : Liquid Metal (cooled) Fast Neutron Reactor
GCR : Gas Cooled Reactor (Magnox and UNGG)
HM : U + Pu + Am
HTR : High Temperature Gas (cooled) Reactor
IAEA : International Atomic Energy Agency
LWR : Light Water (cooled and moderated) Reactor
MA : Minor Actinides (Am, Cm, Np, etc...)
MOX : Mixed Oxide (U, Pu)O_2
MSR : Molten Salt (cooled and refuelled) Reactor
NATO : North Atlantic Treaty Organization
NF : Nuclear Fuel
NPP : Nuclear Power Plant
OECD : Organization for Economic Cooperation & Development
ORNL : Oak Ridge National Laboratory
Put : total Pu, i.e. all the Pu isotopes and the Am 241 resulting from decay of Pu 241
RIA : Reactivity Initiated Accident
RPu : Reactor grade Pu
START : Strategic Arms Reduction Treaty
UOX : Uranium Oxide (UO_2, generally U enriched)
WAGR : Windscale AGR
WPu : Weapon grade Pu