P&T POTENTIAL FOR WASTE MINIMISATION IN A REGIONAL CONTEXT

M. Salvatores (ANL, CEA-Cadarache), E. Schneider (LANL), J.P. Grouiller (CEA), A. Schwenk Ferrero (FZK), H-W. Wiese (FZK), M. Delpech (CEA), J. Knebel (FZK)

Abstract

P/T strategies can be seen not only at a national level, but rather at a regional level, to allow a share of the costs of their implementation, even if the different "regional" partners (countries) can have different policies, e.g. with respect to future nuclear power development. The paper gives practical examples, and points out the potential benefits of the regional approach.

Introduction

Waste management minimisation strategies making use of partitioning/transmutation technologies have not yet been implemented in practice. They imply the development of new technologies and of dedicated installations for the fuel cycle, which can represent a heavy burden if deployed by a single country in isolation. A new concept has been recently proposed [Ref. 1], which suggests the development and use of shared "regional" installations which can serve to meet the objectives and requirements of different countries. This regional concept recognizes and meets a critical constraint: those countries within a given region (e.g. geographical area) may possess different nuclear power development policies/constraints.

One could envision a regional strategy in which, depending on the demand for nuclear energy, the actinides might be transmuted in a dedicated onsite reactor park, or they might be refabricated into homogeneous TRU fuel for use in a Generation-IV converter or breeder. The regional centers must adapt to time-varying demands, and they must expect to receive and treat a strongly heterogeneous stream of spent fuel (SF). This paper shows that the heterogeneity should be seen as a primary strength of the regional strategy.

In this paper we will discuss two quantitative applications of the "regional" scenario concept, in which two different P/T approaches are deployed, namely the homogeneous recycling of not-separated TRU in Generation-IV (Global Actinide Management) reactors, and the transmutation of MA in dedicated reactors, according to the so-called "Double strata" fuel cycle approach. Use was made of two system study codes, NFCSim and COSI [2, 3].

Finally, it is worthwhile to note that the concept and its applications presented in this paper, can be seen as consistent with very general, politically oriented proposals, such as those discussed in Ref. 4 and 5.

Country A and Country B: Generalised regional strategies

The case studies presented here consider two generic nations, *Country A* and *Country B*, having divergent nuclear energy strategies. *Country A*, although it has an operating reactor fleet, has decided to restrict itself to an open fuel cycle. The country possesses an inventory of spent fuel, which may increase in size if it continues to use nuclear energy. Countries that might fall into this category include Germany, Switzerland and Sweden.

Country B, on the other hand, pursues a closed fuel cycle. *Country B* has an ongoing commitment to using MOX fuel; it might move toward infinite recycle of MOX, implementing the MOX-UE scheme or save Pu for future use in a fast neutron system (Generation-IV). The country's reactor fleet may be relatively static in size, or it might be expanding. Minor actinides from discharged oxide fuel reprocessing constitute the country's waste stream to be transmuted. This model might depict France or Japan as examples of mature nuclear economies, or China as an expanding user of nuclear energy.

Figure 1 illustrates two mechanisms by which *Countries A* and *B* might establish a synergistic relationship in the context of a regional strategy.

- Scenario 1: "Regional Burn and Develop" (RBD) : actinides are transferred from *Country A* to *Country B*. *Country B* implements Gen-IV Fast Neutron Reactors (FNR) and actinide recycling

- Scenario 2: "Regional Blend and Burn" (RBB) : *Country A* and *B* implement common facilities to burn actinides and to reduce waste inventory and toxicity

- Scenario 3: "Business as Usual": no reduction in waste inventory and toxicity.

Scenario 1 (RBD), postulates that one of the Generation-IV concepts matures into an appealing option for commercial deployment. Country B chooses to deploy these facilities to supplement – or perhaps eventually to replace – its Generation-III+ LWR fleet. Regardless of the conversion ratio at which these reactors operate, they would require, during startup mode, plutonium feed, depending on the expansion rate.

Figure 2 shows how a regional "Burn and Develop" (scenario 1) can be represented. Several options for Generation-IV development in *Country B* may be considered:

- Development of Fast Reactors (FR):

  a) with homogeneous recycling of not-separated TRU,

  b) with Pu fuel and MA targets.

- Development of Pu-loaded reactors with MA are sent to a waste repository.

Co-located installations would include fuel reprocessing and repository. Fuel fabrication plants could also be located on site.

This strategy based on the introduction of Generation-IV plants replacing the existing power fleet of *Country B*, could avoid shortages of Pu without the need to introduce fertile blankets or to enhance the internal breeding gain.

In Scenario 2 of Figure 1, "Regional Blend and Burn", *Country B* continues to deploy MOX-burning Generation-III+ LWRs. *Countries A* and *B* together confront their waste legacies through deployment of a regional park of dedicated transmuters, assumed here to be accelerator driven systems (ADS).

It is assumed that *Country A* phases out its reactor fleet during the early part of this century and is left with a spent fuel legacy. *Country B*, having a mature nuclear economy with temporally constant LWR generation capacity, adopts MOX multirecycling. In this case, Regional Blend and Burn would develop as shown in Figure 3. The co-located regional facilities would include both oxide and transmuter fuel reprocessing plants as well as the transmuters themselves. An interim storage facility, or perhaps a repository, for vitrified fission products and actinides lost in reprocessing would also be needed.

An example of "Blend and Burn" (scenario 2)

Simulation of this regional "Blend and Burn" scenario has been performed with the NFCSim code [Ref. 1]. To assess the impact of the strategy, five cases were analysed:

Case I: Assessment of the Pu and MA stockpiles of Country A in 2022.

Case II: Partitioning and ADS Transmutation of Country A SNF (Reduced actinide disposal).

Case III: Characterization of Country B MOX-burning reactor fleet (Partial actinide recycle).

Case IV: Double strata approach in Country B (Actinide recycle).

Case V: The "regional" strategy: ADS transmutation of Country A TRU plus Country B MA (Regional actinide recycle).

Here we will describe the major results, in order to underline the potential benefits of the "regional" strategy (Case V), as compared to the case where transmutation is pursued independently in each country (Cases II + IV).

Spent nuclear fuel of a country A with phase-out scenario

To assess the stockpiles of Pu and MA in the spent nuclear fuel (SNF) of a Country A, the case of a progressive phase-out of the nuclear power fleet of Germany, presently foreseen in 2022, was considered. The German fleet, 13 PWRs and 6 BWRs, some of them MOX-fuelled (≈60%), provides approximately 20 GWe. The NFCSim calculation of the evolution of the SNF inventory, accounting for an early stop (≈2005) to SNF reprocessing, predicts Pu and MA inventories in 2022 as given in Table 1.

Table 1. **Inventories (tons) of German SNF and HLW as of January 1, 2022**

Quantity	**PWRUOX**	**PWRMOX**	**BWRUOX**	**BWRMOX**	**Total SF**	**HLW**
Total	5350	773	3470	246	**9840**	2.15E+02
U	5060	702	3310	227	**9290**	6.64E-01
Pu	51.7	34.3	32.9	7.95	**127**	2.01E-01
Np	3.6	0.234	2.16	0.0497	**6.04**	2.94E+00
Am	4.6	4.96	3.48	1.17	**14.2**	3.63E+00
Cm	0.23	0.226	0.148	0.0644	**0.669**	7.36E-02

In 2022, the SF will contain 127 tons of plutonium. In the vitrified high level waste (HLW), the bulk of the mass (≈96.7%) is contributed from the fission products. The trace actinides follow from the assumed 99.8% recovery efficiency of all transuranics.

Figure 4 shows the evolution from 1970 to 2022 of the cumulative discharged SF and its breakdown to the existing SF inventory and the cumulative SF reprocessed. Through 2000, 8400 tHM were discharged, of which 4000 tHM had been reprocessed. At the time reprocessing ceases in 2005, 7000 tHM will have been reprocessed. These three temporal data points describe the performance of the German nuclear power fleet as a consequence of adjusting the MOX utilization by individual reactors in the NFCSim input.

By 2022, 16840 tHM will have been discharged from German reactors. Reprocessing and utilization of recovered plutonium in MOX fuel reduces the heavy metal to be finally disposed of to 9840 tons, i.e. by 42%.

Case II: Partitioning and ADS transmutation of *Country A* spent fuel

This scenario evaluates the degree to which accelerator driven systems could contribute to mitigating the burden of SNF disposal for *Country A*. An ADS park is deployed beginning in 2030. The ADS park is sized such that all *Country A* SNF is reprocessed during the 40 year lifetimes of the ADSs. Subsequently, a smaller fleet of 'second generation' ADSs is deployed as the first generation facilities retires. Hence, the simulation commences in 2030 and extends approximately 100 years, about two facility lifetimes. The progress made in reducing actinide inventories in 2100 as well as upon retirement of this second generation is assessed.

The ADS is a Na-cooled, metal-fuelled facility with an LBE target. Table 2 provides a summary of parameters used for this facility and its associated fuel cycle. ADS fleet size is determined by the amount of material available for transmutation: the fleet must be of sufficient size to take up, as nearly as possible, the entire *Country A* SNF inventory during the lifetimes of the first generation of transmuters (40 years). Hence, eight 840 MWt facilities were deployed in the first generation and three in the second, since half of the TRU content in SNF was transmuted by the first generation.

Table 2. **Top-Level ADS design parameters**

Target K_{eff}	0.97 (BOC); 0.94 (EOC)
Core Inventory	3000 kgIHM
Thermal Power	840 MWt
Discharge Burnup	200 MWd/kg
Fuel Management	5 batches / core
Cycle Time	168 days (142.9 efpd)

In this strategy, since plutonium constitutes ~85% of the TRU contained in *Country A* SNF, the ADSs used to transmute that TRU must necessarily employ relatively short cycles. In fact, it was found that the steep burnup reactivity gradient resulting from use of the *Country A* TRU inventory limited the ADS cycle burnup to 40 MWd/kg (with a reactivity swing $\Delta k_{eff} = 0.03$) and cycle time to slightly less than one half of a year.

In addition to reducing SNF volumes, a fivefold reduction in plutonium inventories over two generations of ADS operation is achieved: see Figure 5. The figure also shows that significant reduction of MA inventories, on the order of 50 – 75%, is achieved. This does not include those MA that were vitrified prior to the cessation of reprocessing in 2005.

To quantify the implications of this strategy on disposal options, the decay power of all nuclear material in the system was evaluated. The long term decay heat – the decay power integrated over a period extending from 100 to 2000 years in the future – is shown in Figure 6. This heat production metric has been identified as one of the most significant performance drivers for the Yucca Mountain repository. Since transuranics, particularly Am-241 and Pu-238, dominate heat production on this time scale, destruction of most of these isotopes via transmutation offers a substantial benefit: the decay heat production is reduced by a factor of four following two generations of ADS operation.

A transmuting fleet consisting of accelerator driven systems can thus significantly alter, and by most metrics reduce, the burden of spent fuel and waste disposal. In view of the large investment required, though, this strategy is questionable. We will see later that the regional approach will drastically change this situation.

Case III: Characterisation of *Country B* MOX-burning reactor fleet

This scenario characterizes the behaviour of *Country B's* large (ca. 60 GWe) reactor fleet in a quasi-equilibrium state in which successively higher passes of MOX are being used. The *Country B* fleet is simplified: generation capacity is held essentially constant during the 2030-2100 period of interest. Also only one type of reactor, with fixed power and core inventory, is deployed to meet energy demand, and burn-up and availability are held constant through time. This reactor is a 1450 MWe PWR resembling the French N-4. Table 3 lists reactor and fuel cycle parameters for this scenario.

Table 3. **Top Level Reactor and Fuel Cycle Parameters**

Thermal Power	4250 MWt
Net Electric Power	1450 MWt
Core Inventory	125.6 tIHM
Equil. Discharge Burnup	60 MWd/kg
Refueling Strategy	4 batches / core
Cycle Time	609 days (548 efpd)

NFCSim calculated that UOX-fuelled reactors use uranium enriched to 5%. These facilities are assumed to be capable of burning either UOX or full-core MOX. For MOX-burning reactors, the MOX-UE scheme is used. Under the scheme, the initial plutonium content of fuel batches must be less than or equal to 10%. On MOX passes subsequent to the first, for a given fuel batch 10% plutonium content is reached via recovery of plutonium from one batch of the previous MOX generation, plus top-up obtained from recycle of the requisite amount of UOX fuel. Given that higher pass plutonium cannot provide sufficient reactivity surplus, enriched uranium support is required for the fuel to reach the 60 MWd/kg target burn-up.

Successive MOX passes are deployed every 14 years, with second pass MOX being loaded beginning in 2015. By 2090 seventh pass MOX is being burned and MOX fuel provides 30% of total energy. Figure 7 shows that plutonium inventories are stabilized at around 400 tons system-wide. This number is a function of the size of the fleet, minimum cooling time and equilibrium burn-up; it is independent of initial conditions.

Minor actinides are produced at an increasing annual rate due to the growing MOX share of generation. By the last part of the century, when the fraction of capacity filled by MOX levels off, about 4 tons MA are being produced at separations per year: see Figure 8. After nearly a century of MOX use, the amount of separated MA requiring storage or vitrification approaches 300 tons.

Double strata approach in Country B (Case IV)

In the “double strata” scenario for *Country B*, as opposed to the transmutation of a fixed-size SNF legacy in *Country A*, the ADS feed stream is a continuously produced time-varying stream of MA. It appears unlikely that ADS startup cores may safely be constituted exclusively from MA feed. Therefore, some Pu-containing SF from the LWR park is diverted for the purpose of fabricating initial ADS cores. This is done by delaying the time between introduction of the third and subsequent MOX passes by 5 years, from 14 to 19 years. The extra Nth pass MOX SF obtained by delaying burning N+1 th pass MOX becomes available for use as feed to the ADS park. This partial use of Pu for ADS deployment is such that MOX provides only 26% of generation capacity in 2100, as opposed to greater than 30% as in Case III.

Accelerator driven systems are deployed beginning in 2030. To maintain comparability between this scenario and Case II, the ADS design parameters are held constant. The more favorable feed, however, allows certain fuel cycle parameters to be improved. The discharge burn-up is changed to 210 MWd/kg with a 2 batch/core reloading scheme. Charge and discharge k_{eff} values remain the same, at 0.97 and 0.94 respectively.

Twelve cores are deployed in the first generation; deployment is staggered with pairs coming online every four years. Deployment is slower than was the case for *Country A* transmutation, as the MA to be transmuted by *Country B* become available only gradually. Hence, new ADSs are delayed until sufficient MOX SNF and separated MA become available to provide startup feed. The second generation, replacement ADSs, consists of sixteen cores. A larger number of facilities is required because the growing number of MOX-using reactors discharges an increasing quantity of minor actinides.

System wide (in plus out of pile) plutonium inventories are shown in Figure 9. Again system wide Pu equilibrates at approximately the same level: in Case III 31% of electrical generation capacity is provided by MOX in 2100, while the ADS case has 26% MOX and 7% ADS capacity installed.

Figure 9 also shows the effect of ADS deployment on separated MA inventories to be sent to repository. Given that ADS generation capacity must be added in increments of finite size, there will always be a small MA inventory. The deployment schedule was selected to minimize this. A gradual decline in the MA inventory from 2030-2050 corresponds to the phased introduction of the first generation of ADSs: each new ADS coming online requires about 4 tons of MA to cover the five years in which it operates in startup mode. Once an ADS enters reload mode, its MA demand drops to 0.25 tons/year.

The infinite-recycle MOX strategy of Case III reduces the mass and volume of waste (Pu losses and MA) to be disposed of but not its decay heat or radiotoxicity. The fully closed cycle completes the job, significantly reducing these two important metrics as well. Defining repository-bound waste as separated actinides plus vitrified HLW, the long-term integrated decay heat burden for Cases III and IV is as shown in Figure 10. This figure shows that significant (order of magnitude) long-term reductions in the heat production of the waste are obtained once quasi-equilibrium is reached.

Case V: A regional strategy: ADS transmutation of *Country A* transuranics plus *Country B* minor actinides

In this scenario, the two nations' waste streams are blended in a time-varying manner and transmuted together in a shared ADS fleet, as an example of a "regional blend and burn" strategy. As in Cases II and IV, ADSs are deployed beginning in 2030. For this case, the individual countries' objectives must be combined. Given that the ratio of plutonium to minor actinides in ADS top-up feed can be adjusted, the rate at which *Country A* SNF is reprocessed becomes a free variable. Hence the ADS fleet size and cycle burn-up characteristics may be controlled by increasing or decreasing the rate at which transuranics are drawn from *Country A* SNF and blended with *Country B* MA.

It is necessary to choose a target date, the time by which all *Country A* SNF is to be reprocessed. Here, with the SNF and MA to be transmuted taken from the results of Cases I and III, this date was chosen to be the year 2100. Figure 11 shows a conceptual materials flowchart for this strategy. The numerical values given for mass flows to the ADSs reflect the 2100 target date: adjusting the rate at which mass is withdrawn from the SNF stockpile is equivalent to changing this target.

One of the benefits of this strategy is that drawing from both the *Country A* plutonium and the *Country B* MA inventories can allow the feed composition to the ADS to be adjusted to maintain the most favourable isotopic distribution. In fact, rather than optimizing on the rate at which *Country A* SNF is consumed, this scenario could be optimized on the basis of best ADS performance. For this facility design, a roughly equal plutonium to MA balance at charge is ideal, allowing the largest cycle burn-ups. Given the SNF and MA compositions, the ADS was found to best use the inventories if it burns fuel to 210 MWd/kg with a 2 batch/core reloading scheme. As before, k_{eff} is targeted at 0.97 at BOC and 0.94 at EOC. Other ADS parameters remain as specified in Section 0.

Table 4 shows that the maximum number of ADS to be deployed in Case V is reduced by 4 units with respect to the sum of the units to be deployed in cases II plus IV and that the time integral of the deployed ADS capacity from 2030-2100 is reduced by 13% under the partnership strategy. ADSs generate 11% less electricity (assuming that all plants deliver a constant 275 MWe to the grid when operating) in the partnership case.

Table 4. **Facility deployment impacts of transmutation strategies**

	Case II: Country A	Case IV: Country B	Case V: Regional Blend and Burn	**Difference: (II+IV) - V**
Maximum # of 840 MWt piles deployed	8 (2040-2070)	16 (after 2085)	20 (after 2095)	**4**
Intergated Capacity Deployed [GW_t-yr]	332	563	781	**114**
Integrated Electrical Generation [GW_e-yr]	282	507	703	**86**

Moreover, in the Regional scenario only one reprocessing and fuel fabrication facility has to be implemented and, potentially, only one repository.

Results

The system wide inventory of SNF of all types (UOX and MOX of any pass number) is shown in Figure 12. The jump in the SNF inventory for the combined case in 2022 follows from insertion of *Country A's* SNF into the system. As described above, the ADS fleet was sized and deployed such that essentially all of the *Country A* SNF is reprocessed by 2100. The *Country B* SNF inventory is that of Case III and consists of UOX and MOX fuel that is awaiting reprocessing. Effort was made to keep the post-2030 *Country B* out of pile fuel inventory as low as possible given cooling requirements.

The system wide inventory of separated minor actinides arising from reprocessing of MOX fuel is shown in Figure 13. This figure is analogous to Figure 9 of Section 0: the ADS fleet takes up the 30 ton backlog existing in 2030 and subsequently consumes *Country B* MA at the rate they are produced. The ADSs obtain the plutonium component of their feed from *Country A's* SNF. In 2022, this SNF contains ~ 130 tons of Pu. By 2100, the system wide plutonium inventory has equilibrated at a level about 50 tons higher than was the case for the *Country B* fleet alone, reflecting the amount of plutonium circulating through the ADS fuel cycle.

The disposability of the waste present in 2100 is compared in Figure 14 for the non-transmuting Cases I and III versus the Regional Blend and Burn strategy of Case V. Two metrics are used: the long-term integrated heat production (as defined for Figures 6 and 10) and the 10000 year radiotoxicity. The radiotoxicity is evaluated as the dilution required to meet inhalation dose guidelines. In this figure, waste is defined as *Country B's* separated actinides plus other vitrified HLW (fission products plus actinides lost in reprocessing) plus *Country A's* SNF. This is the sum of the untransmuted discharges of Cases I and III. In Case V, only the vitrified HLW is destined for a repository.

The collaborative strategy outlined here accomplishes the same transmutation goals as the two separate strategies of Cases II and IV. This strategy, implementing facilities similar to those defined in the 2002 OECD study, appears comparable in feasibility and expected unit costs. The reductions in the heat load and radiotoxicity were assessed in a time-dependent context. If the transmutation program is carried out indefinitely, the repository waste is only separated fission products plus trace actinide losses incurred during reprocessing. In that case, the reduction of any disposal-relevant metric (heat load, radiotoxicity, volume) is definitively larger (by approximately 2 orders of magnitude).

Application to a Gen-IV development scenario

As an example of the regional scenario "Burn and Develop" (RBD), schematically illustrated in Figure 2, we have considered the case of *Country B* introducing Gen-IV reactors (GFR in this example) starting in 2035, which will replace completely the existing power plant fleet by 2080. The existing stocks of TRU of *Country A* will be used to allow the implementation of the strategy of *Country B*.

Figure 15 gives the installed power in *Country B* (60 GWe producing 400 TWhe) with the replacement of Gen-II fleet by Gen-III reactors (EPR-type) starting in 2020 and by Gen-IV reactors (GFRs, iso-generators) starting in 2035 with complete replacement by 2080.

The scenario (evaluated with the COSI code, Ref. 3) has 3 phases :

1. Up to 2025 the Pu issued from UOX reprocessing is recycled as MOX in Gen-II PWRs (30% MOX, 70% UOX), and Gen-II UOX PWRs are progressively replaced by Gen-III EPRS, loaded with UOX.

2. Part of the Pu plus MA separated after 2020 are recycled starting in 2035 in GFRs, which represent 50% of the total power once all Gen-II reactors are shutdown. The GFRs are iso-generators, i.e. without fertile blankets (or slightly breeders, depending on fuel design). MA generated before 2020 are assumed to be vitrified.

3. Full TRU recycling in the GFRs starting in 2080. At that moment, the whole fleet is made with GFRs (Gen-IV).

Beginning in 2035, the introduction of the GFRs allows the homogeneous recycling of the MA that were separated and stored after 2020.

In 2080, the first EPRs are shutdown (60 years lifetime). They are replaced by GFRs. Additional feed is needed to support the new GFRs. For this purpose, the feed is augmented by the Pu and MA issued from reprocessing of the stocks of *Country A* (10,000 tons of heavy metal, of which 9% is spent MOX fuel). In the reprocessing phase, Pu and MA are co-extracted.

Figure 16 gives the evolution of the available Pu to feed the iso-generator GFRs. The contribution of Pu from the stocks of *Country A* is essential to this strategy: without this contribution, as of 2095 the Pu available in *Country B* would not be enough to fully deploy the new GFRs coming online after 2080. Figure 17 gives the annual reprocessing needs for both *Country A* and *B*. The hypothesis was made that *Country A* stocks are reprocessed over a 30 year period, starting in 2070. This implies that a reprocessing capacity of ~ 1000 tones/year would be needed.

Figure 18 gives the evolution of the MA (Np+Am+Cm) content at the GFR loading. The MA stocks of *Country A* (~ 30 t, with 65% Am), when blended into the fuel, do not significantly affect its MA content, which stays well below any admissible limit.

So far, the hypothesis of constant power over the period considered has been made. If instead we hypothesize a moderately growing energy demand, there will be an increased need for Pu feed. This case will be studied in future, within a wider (i.e. more countries involved) framework.

Conclusions

A regional approach to P/T opens interesting new perspectives for very different scenarios of its implementation. The examples shown in this paper are relevant -

4. to the development of P/T to support waste minimization using dedicated transmuters (in the framework of a “double strata” scenario, and/or a phase-out scenario), and

5. to the development of Gen-IV reactors with a global management of actinides.

Benefits have been quantified using system codes able to handle the time dependent behaviour of any development scenario. The encouraging results enable one to foresee further applications in a wider context of the proposed regional approach.

REFERENCES

[1] M. Salvatores “Nuclear Fuel cycle Strategies Including P/T” in Proc. of the Annual Meeting on Nucl. Tech. 2004, “Düsseldorf, Germany, May 25-27 (2004). An extended version to be published in Nucl. Eng. and Design.

[2] C.G. Bathke and E.A. Schneider, “NFCSim User’s Manual” Los Alamos National Laboratory Technical Report LA-UR-04-XXXX, 2004.

[3] J.P.Grouiller et al, “COSI: a code for simulating a system of nuclear power reactors and fuel cycle plants” Proc.FR’91, Kyoto, Japan, 28 Oct.-1 Nov.,1991

[4] Speech of Director General M. Elbaradei to 47th Regular Session of the IAEA General Conference, September (2003).

[5] V.Gagarinski, Contribution to the US/Russian Lab Directors Meeting, Vienna, Sept. 19-21(2004)

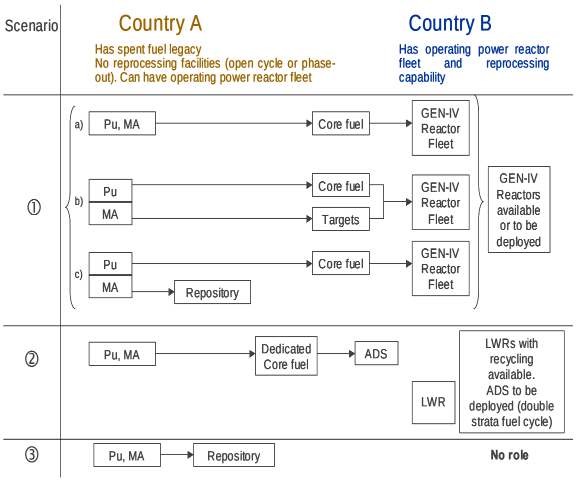

Figure 1. Degrees of Interaction Between Country A and Country B: 1) Regional Burn and Develop, 2) Regional Blend and Burn, 3) No Interaction

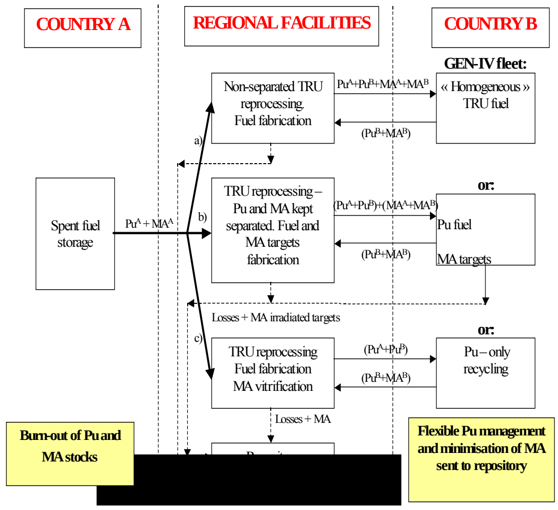

Figure 2. Regional "Burn and Develop" Scenario: Flowchart

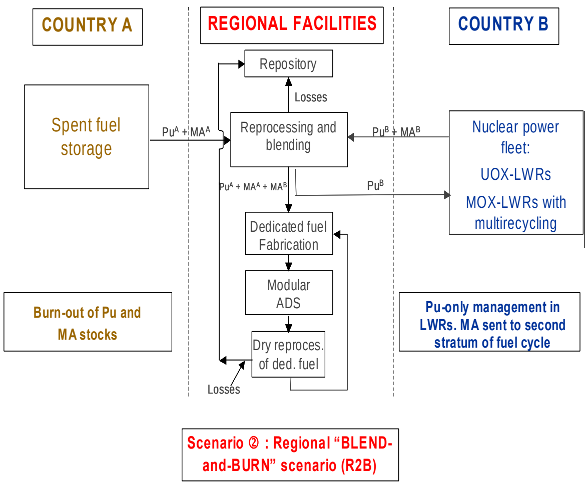

Figure 3. Regional Blend and Burn Scenario: Flowchart

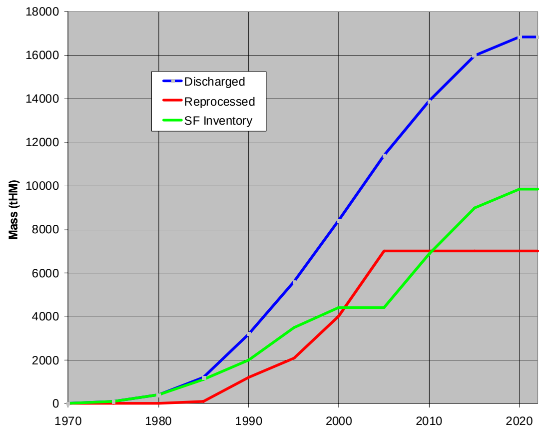

Figure 4. Integrated Discharged Fuel and Reprocessing Throughput, and SF Inventory for German Fleet

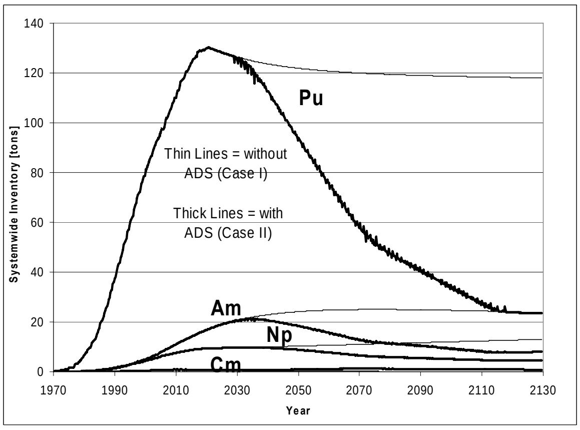

Figure 5. The Effect of ADS Deployment on *Country A* Transuranic Inventories

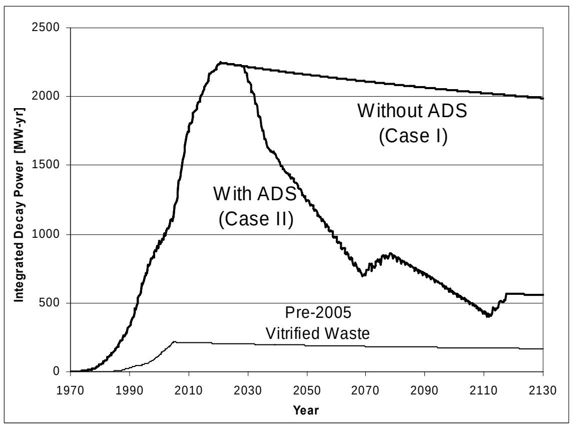

Figure 6. Decay Power of *Country A* Stored Nuclear Material, Integrated over Period from 100 to 2000 years After Date Shown

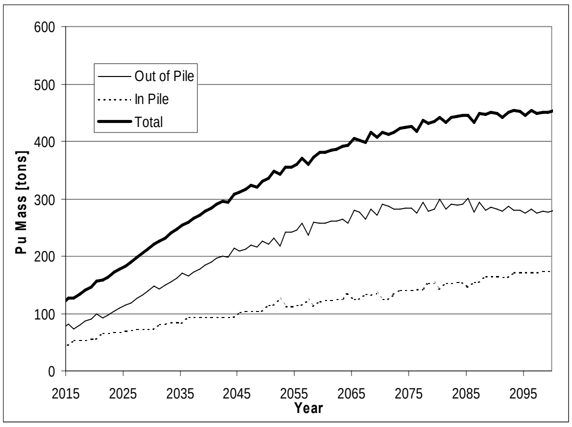

Figure 7. ***Country B*** **Plutonium Inventory by Location and Date for Case III**

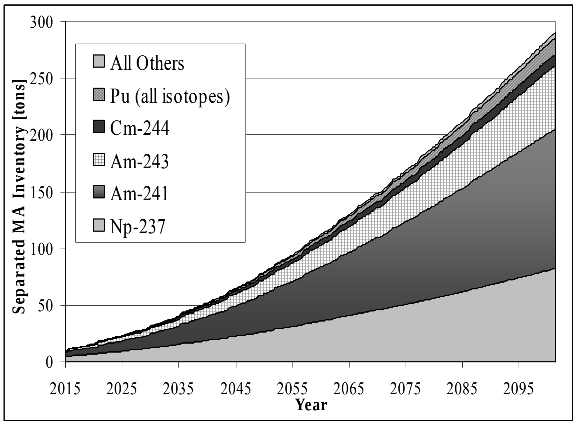

Figure 8. ***Country B*** **Separated Minor Actinide Inventory by Element for Case III**

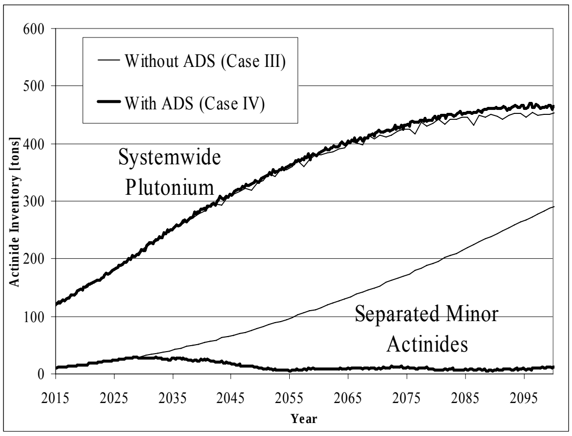

Figure 9. ***Country B*** **System Wide Plutonium and Separated Minor Actinide Inventories**

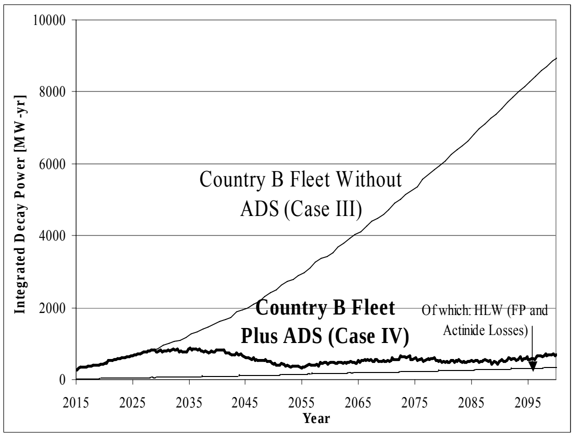

Figure 10. Decay Power of ***Country B*** **Waste Existing at Year X, Integrated From Year X+100 to Year X+2000**

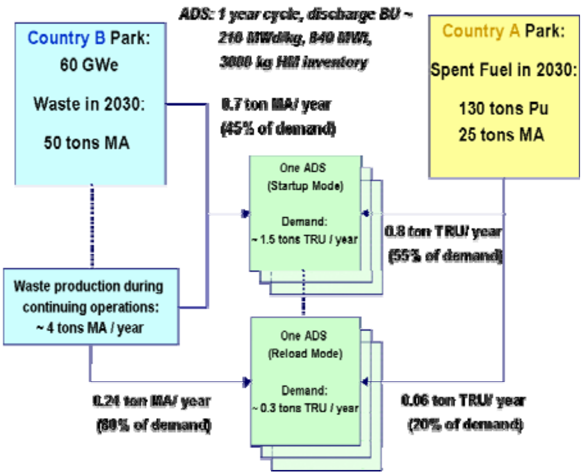

Figure 11. Materials Flowchart for Regional Blend and Burn Strategy as Implemented for Case V

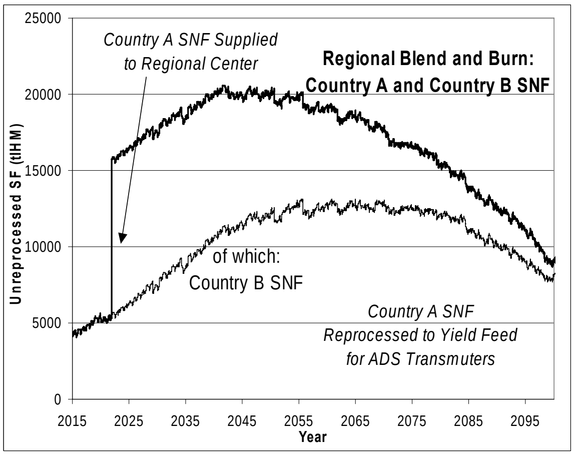

Figure 12. SNF Inventory for Case V, Showing Depletion of Country A SNF

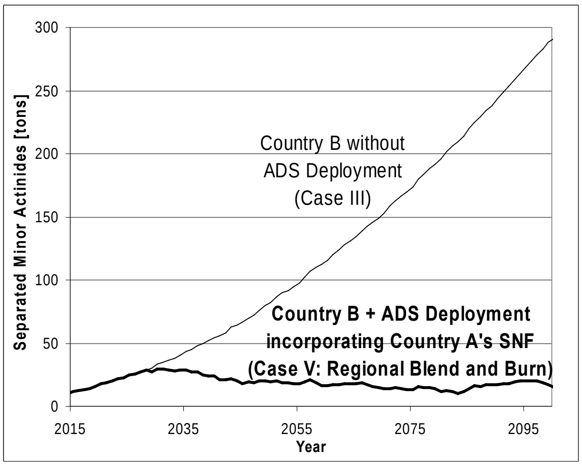

Figure 13. Separated Actinide Inventory for Case V, Regional Blend and Burn

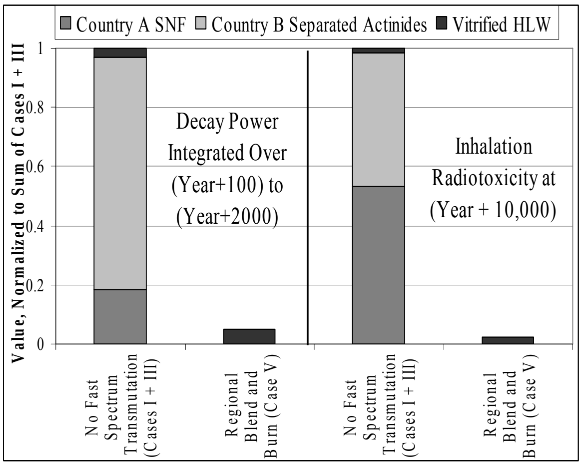

Figure 14. The Long Term: Integrated Decay Power and Radiotoxicity of Waste Existing in 2100

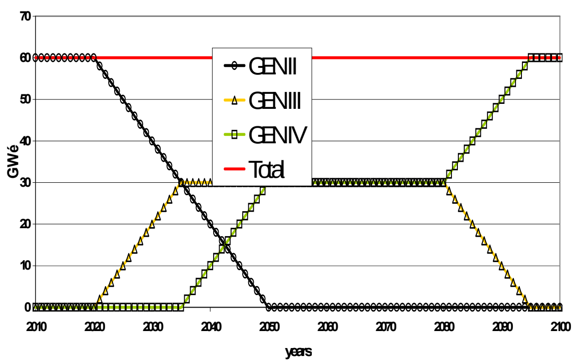

Figure 15. Breakdown of Country B power fleet

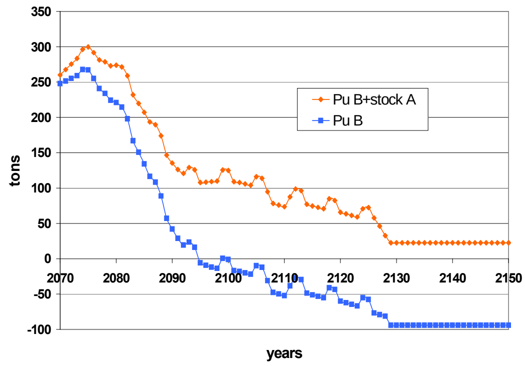

Figure 16. Available Pu for GFR fuel pins fabrication.

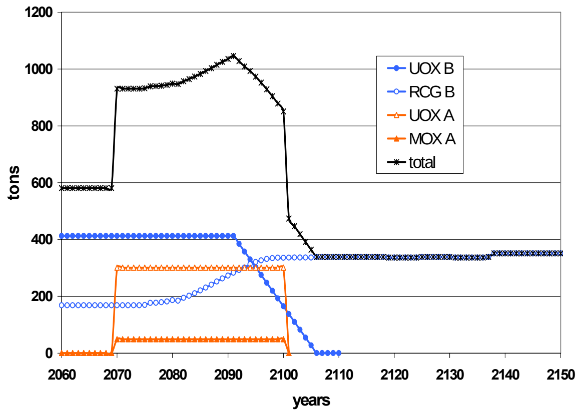

Figure 17. Annual reprocessing

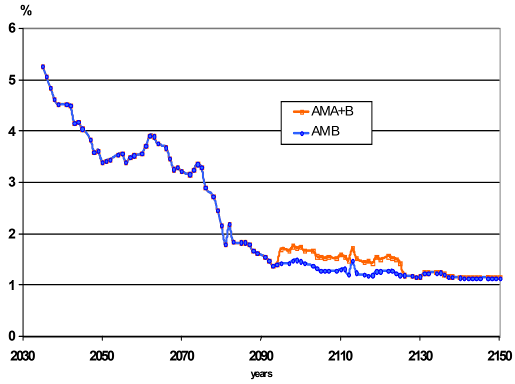

Figure 18. MA (Np+Am+Cm) content in the initial loading