9th NEA Information Exch. Meeting on Actinide and Fission Product P&T,
Nimes, France, 25-28 September 2006

"Improved Resources Utilisation, Waste Minimisation and Proliferation Resistance in a Regional Context"

M. Salvatores (ANL, USA and CEA-Cadarache, France),
L. Boucher (CEA-Cadarache, France)

OUTLINE

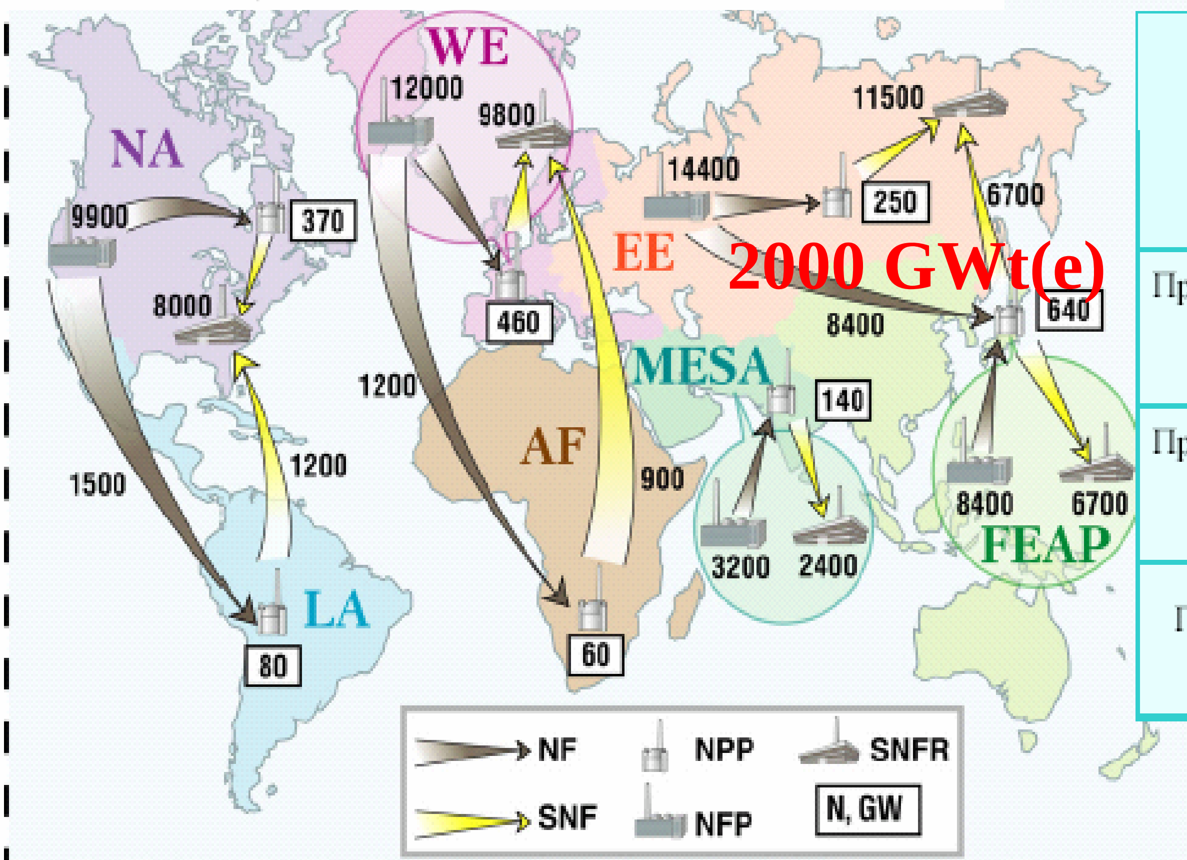
- „Regional approaches“ to the fuel cycle have been proposed, even before El Baradei proposal, mostly for non proliferation reasons.
    - ✓ Some examples
- We developed an original „regional approach“ involving two European countries with a double purpose:
    - To support the deployment of ADS-based waste transmutation.
    - To support the deployment of Gen-IV reactors
    - ✓ Some results will be recalled
- A further application: a “User/Supplier” scenario
- A new development: a more comprehensive study foreseen in the frame of a Coordination Action of the EU

Nuclear energy system vision
Global and regional approach

A.Yu. Gagarinski
Russian Research Centre "Kurchatov Institute"

The present report is a brief description of results of the work currently performed by the Kurchatov Institute's expert group. Completion of this research is scheduled in the second half of 2004.

This work to a certain extent represents the development and quantitative analysis of the vision of the "Second Nuclear Era" considered in the joint 2002 report of Sandia National Laboratories and the Kurchatov Institute. On the other hand, this is a part of Kurchatov Institute's contribution to the INPRO Project, currently realized by the IAEA and dedicated to the analysis of innovative technologies required for the world as a whole and for its separately taken regions for the period of next 50 to 100 years.



Production and trans-regional flows of fresh and spent nuclear fuel in 2050, t/year

	NA + WE + EE		LA + AF + MESA + FEAP	
	NF	SNF	NF	SNF
Производ-ство 2005	16 000	4 800	5 000	1 100
Производ-ство 2050	36 000	29 000	12 000	9 000
Потоки 2050	11 000	9 000		

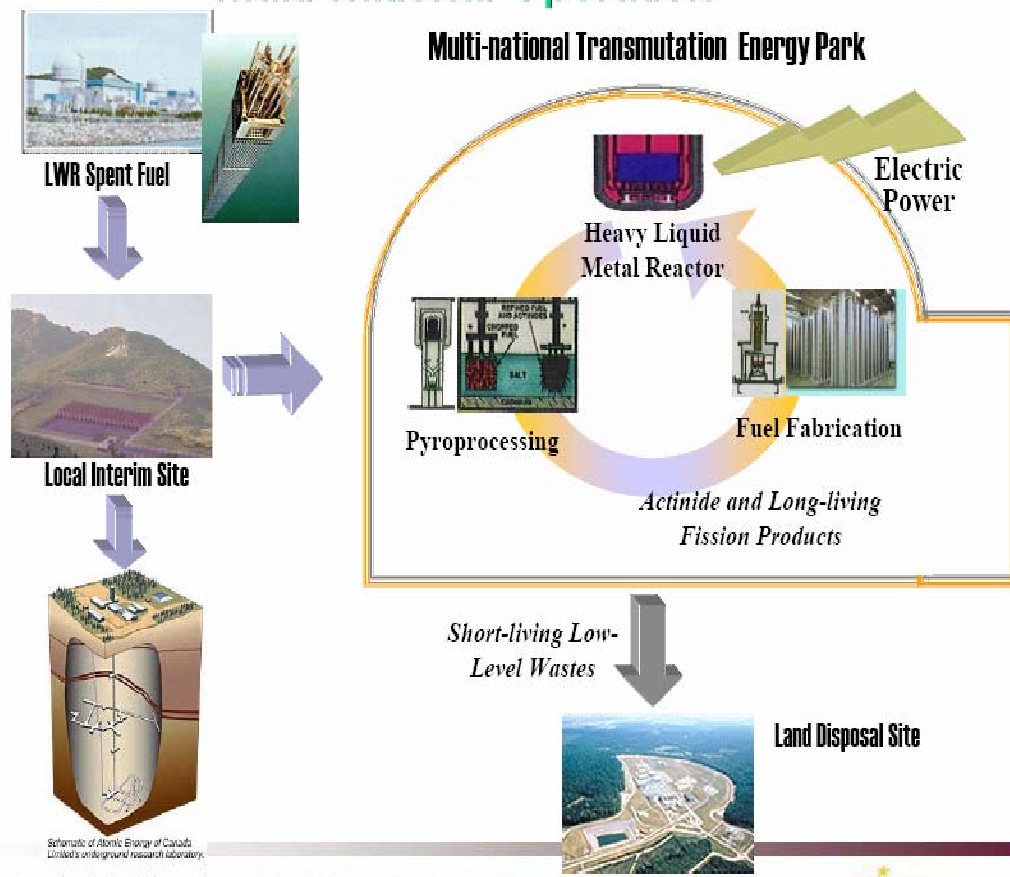
PEACER R&D Update

Il Soon Hwang
Associate Director
Nuclear Transmutation Energy Research Center of Korea (NUTRECK)
Seoul National University, Seoul, Korea
hisline@snu.ac.kr

Prepared for Nuclear Transmutation Group
Los Alamos National Laboratory
2004. 6. 21

Proliferation resistance:

Multi-national Operation



World Nuclear Association Annual Symposium
8-10 September 2004 - London

Nuclear Fuel Cycle Centres - an Old and New Idea

Charles McCombie and Neil Chapman

Abstract

Nuclear technology originally developed in only a few countries – arising out of weapons programmes. In the early years, the concept of nuclear fuel cycle centres was topical. In the 1950s, the IAEA charter itself allowed centralized plutonium storage and management. Studies were performed (e.g. by INFCE) on regional nuclear fuel cycle centres and on international spent fuel management but did not come to fruition. Nevertheless, the fuel cycle was truly international during the 1960s and 1970s, with services such as uranium production and enrichment, fuel fabrication, reprocessing and reactor supply being carried out in a limited number of countries and sold to others. Even the back end of the cycle was to some extent internationalised, with the UK, France and Russia all retaining wastes produced by the reprocessing of foreign fuels.

A first example of a Regional Approach to the Fuel Cycle with P/T

- Different countries can envisage different policies. According to the strategy, specific fuel cycle facilities have to be deployed.
- Some of these facilities are similar, even if conceived for different strategies.
- The multiplication of such facilities is unlikely, both for non-proliferation and economic reasons
- Can a regional (i.e. with some shared installations and combined resources) approach help?

As an example, in a previous study we considered the case of:

➢**A country « A », which has a spent fuel legacy, no reprocessing installations and no decision yet on final repository.**

➢**A country « B », which has an operating power reactor fleet with a waste minimisation objective, has reprocessing capabilities, but looks for an optimisation of resources and investments.**

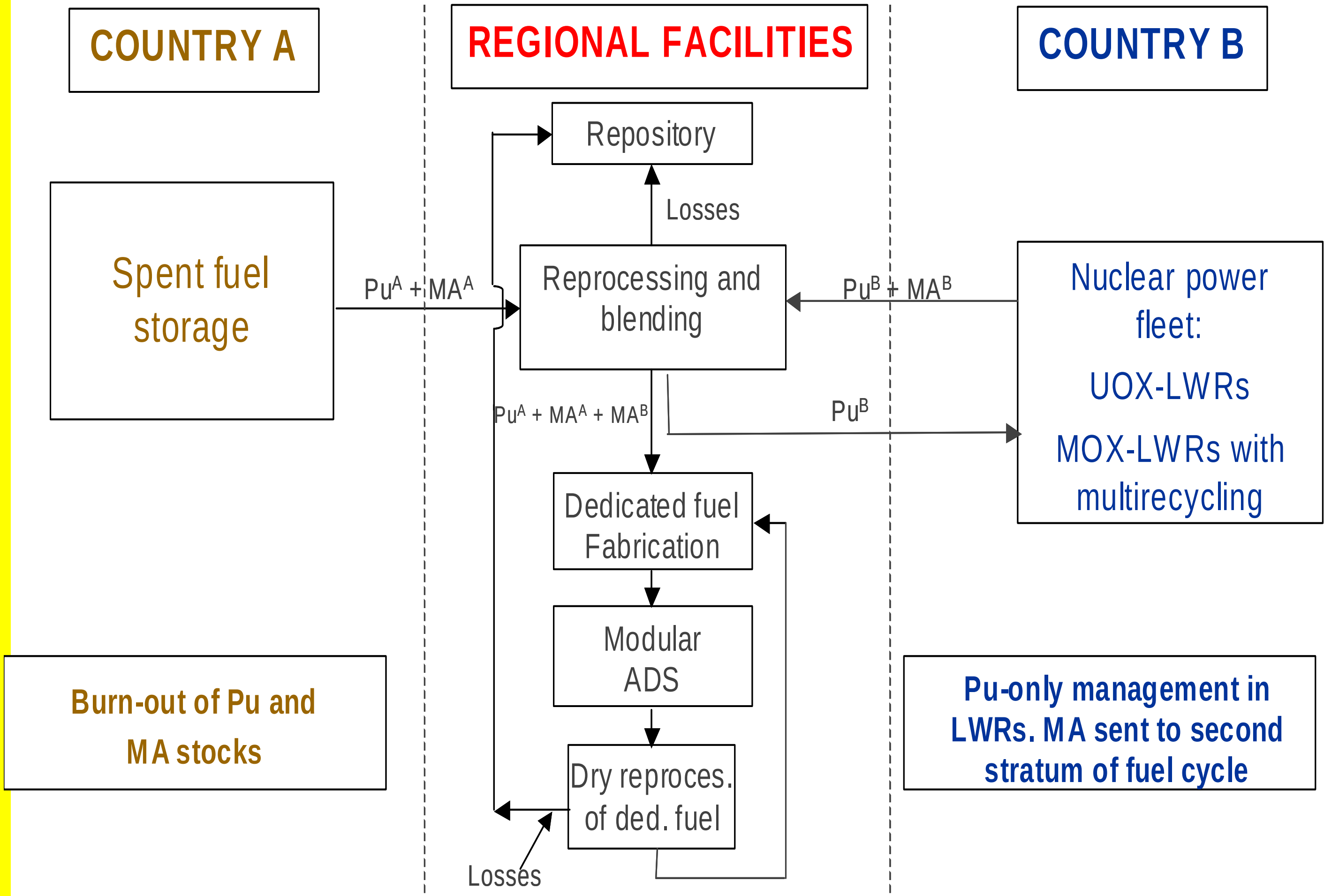
This scenario considers the deployment of a number of ADS shared by the two countries.

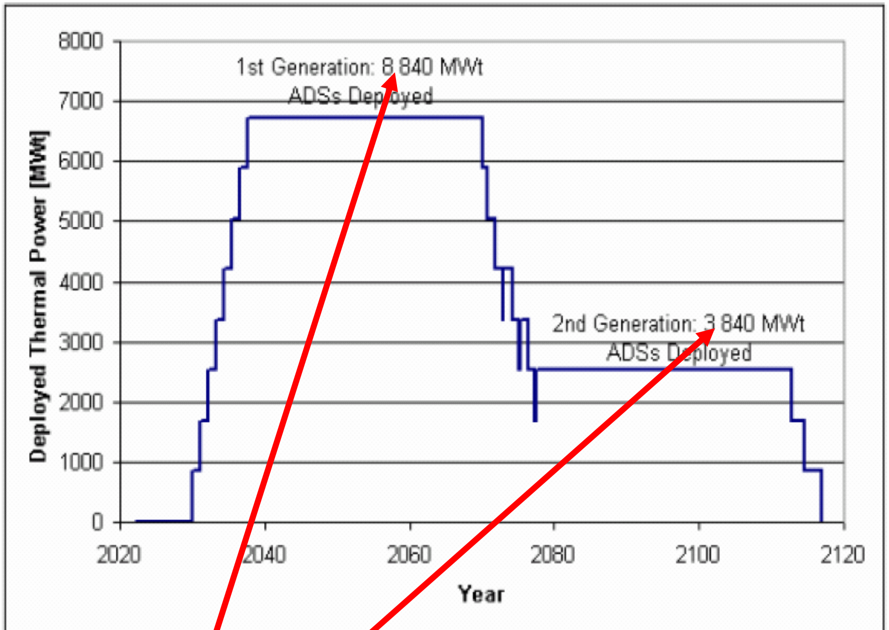
The ADS will use the Plutonium of the country A and will transmute the minor actinides of both country A and B

The Plutonium of the country B is continuously recycled in PWRs.

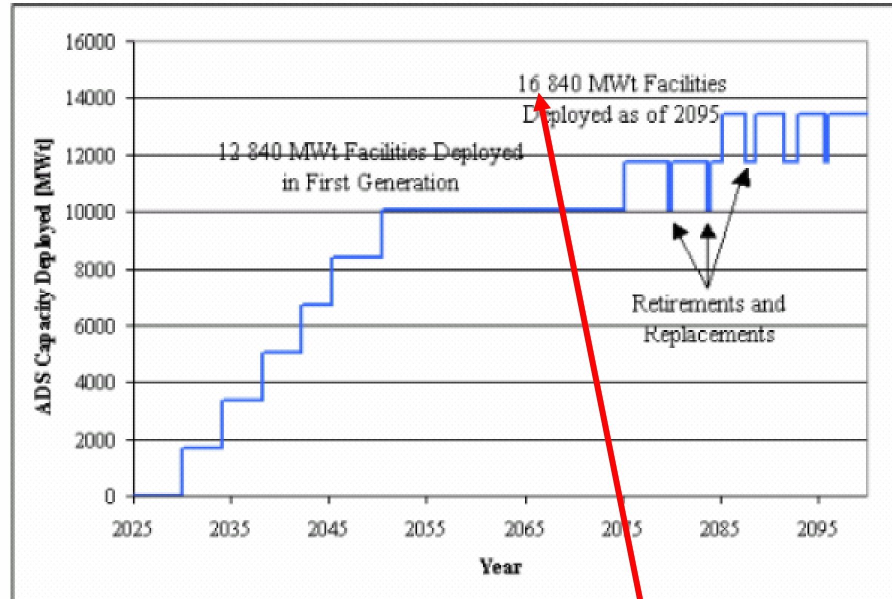
The main objective of this scenario is to decrease the stock of spent fuel of country A down to ~0 at the end of the century, and to stabilize both Pu and MA inventories of country B.

Scenario 1





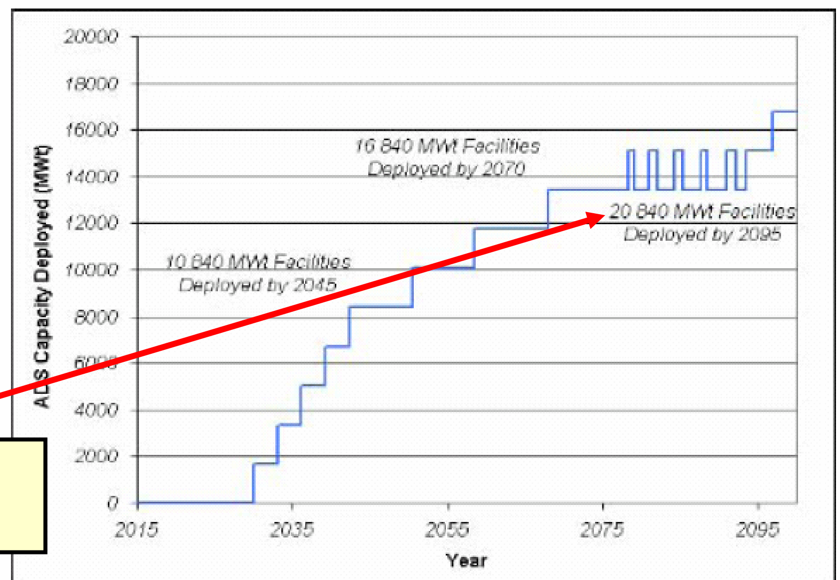
ADS deployment schedule for Transmutation of country A SNF



ADS deployment schedule for Transmutation of country B Minor Actinides

16 ADS needed for Country B in isolation

8+3 ADS needed for Country A in isolation



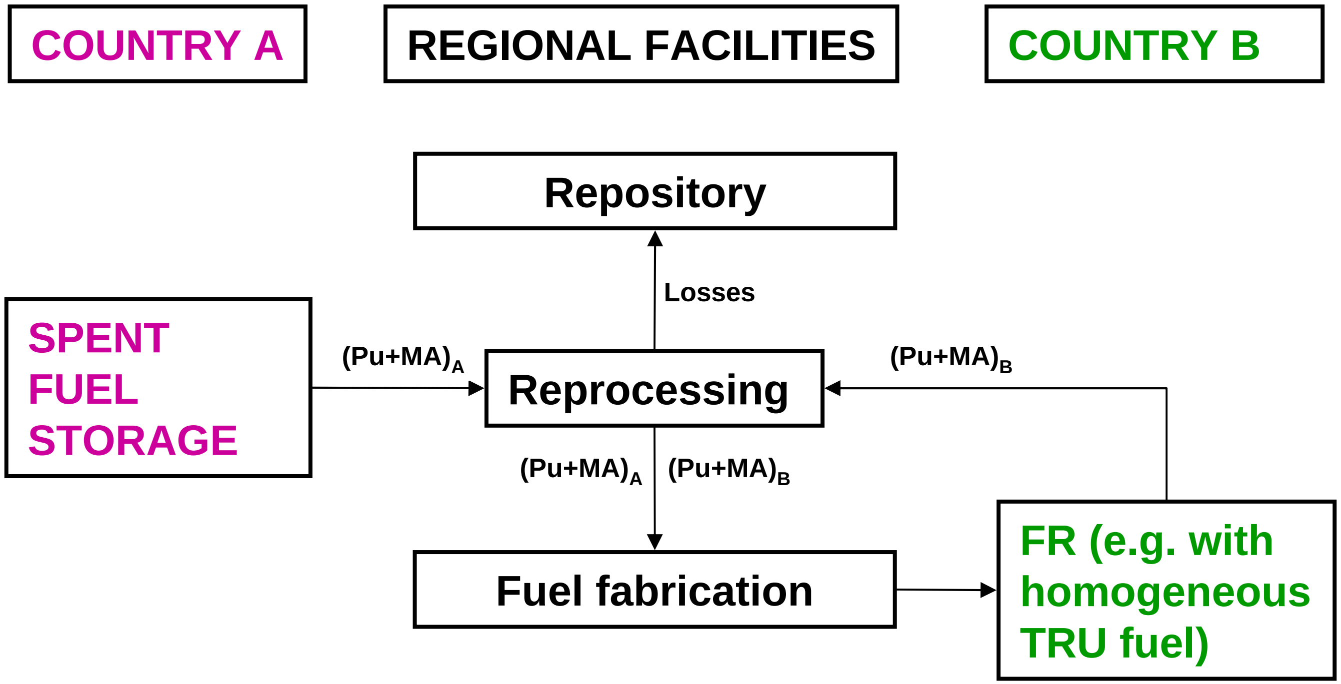
20 ADS needed for a regional Country A+B strategy

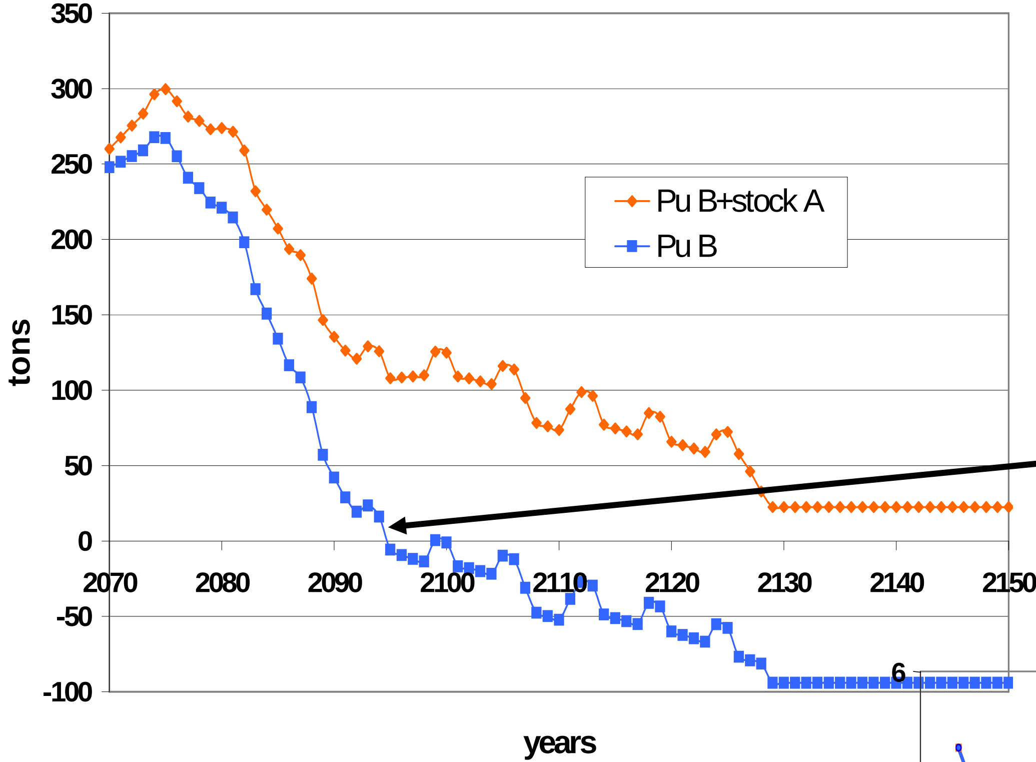
ADS deployment schedule for country A and B

Scenario 2

This scenario considers the deployment of fast reactors in country B. These fast reactors are deployed with the Plutonium of the two countries and recycle all the minor actinides.

The main objective of this scenario is to decrease the stock of spent fuel of country A down to 0 at the end of the century and to introduce Gen-IV fast reactors in country B, starting, e.g., in 2035.

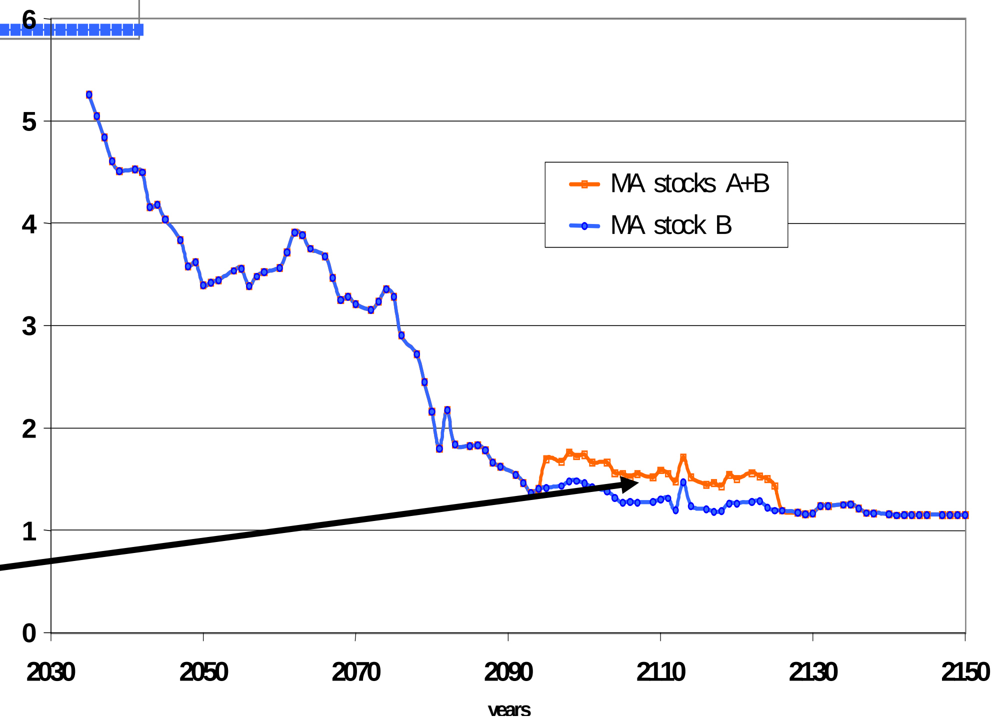




Available Pu for GFR fuel pins fabrication

Need for extra Pu stocks if Country B alone

MA (Np+Am+Cm) content in the initial loading (%)



Increase in content is insignificant

Another possible scenario: a „User/Supplier“ Scenario:

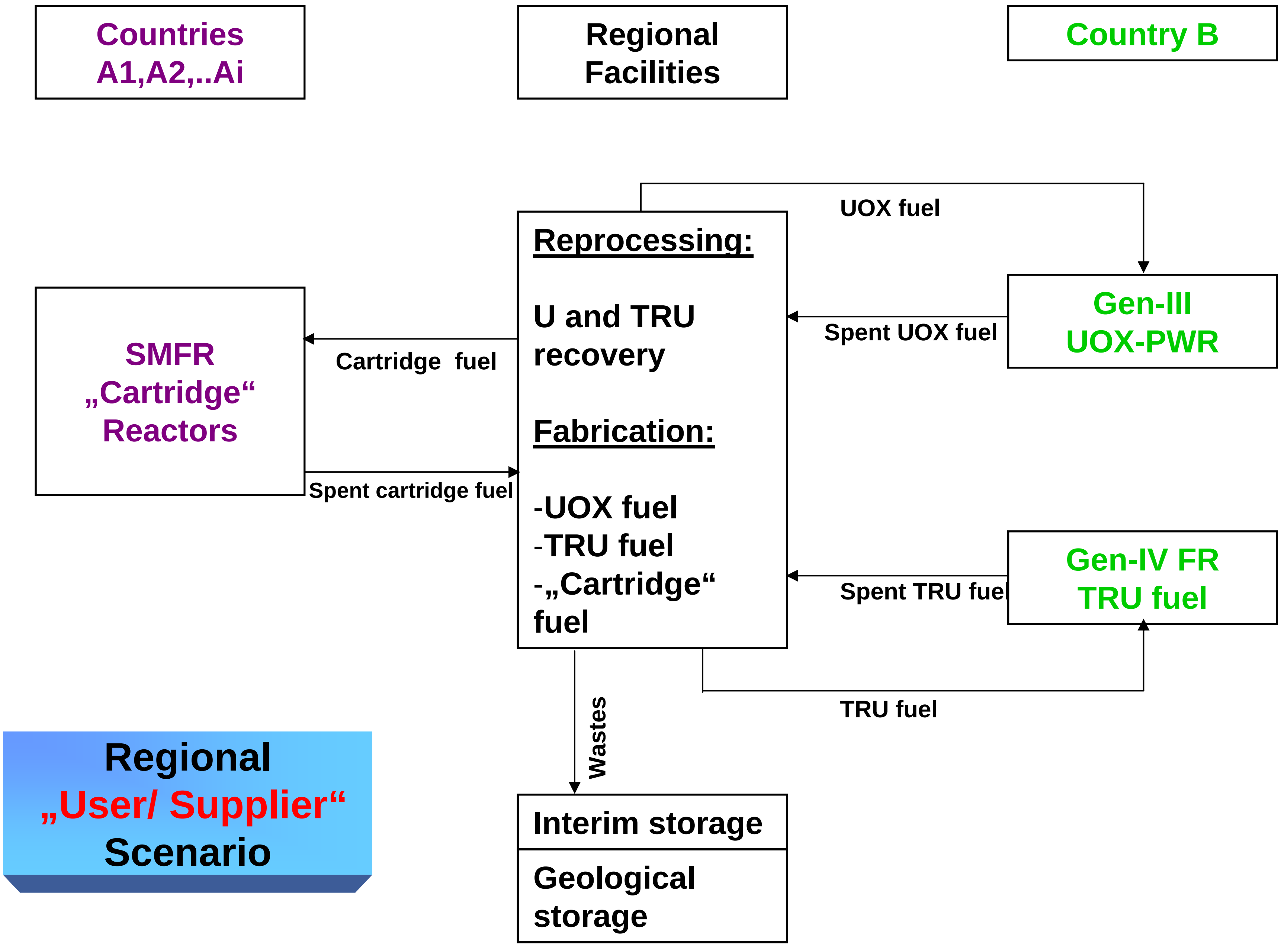
- **Countries „A“ e.g. with small grid systems**

  Small (~50 MWe) reactors as transportable „cartridges“

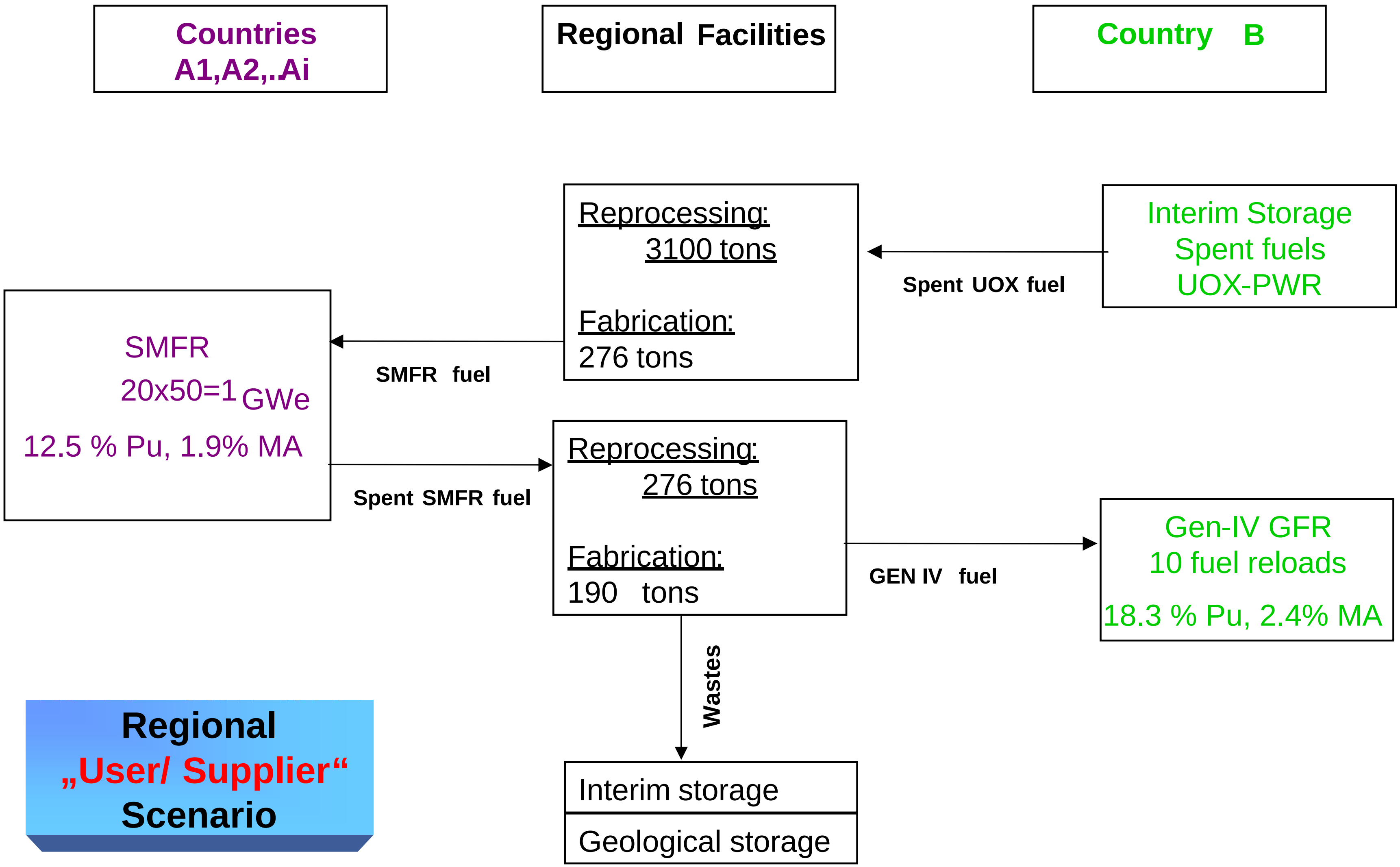
  e.g. SMFR with ~30 years lifetime, passive safety, compact and robust technology, high proliferation resistance

- **Country B with reprocessing and fuel fabrication capabilities, with its own nuclear power fleet**

Objective: quantify fabrication/reprocessing/material transport needs, constraints etc.



Countries
A1,A2,..Ai
Regional
Facilities
Country B
Reprocessing:
U and TRU
recovery
Fabrication:
-UOX fuel
-TRU fuel
-„Cartridge“
fuel
UOX fuel
Gen-III
UOX-PWR
Spent UOX fuel
SMFR
„Cartridge“
Reactors
Cartridge fuel
Spent cartridge fuel
Gen-IV FR
TRU fuel
Spent TRU fuel
TRU fuel
Wastes
Interim storage
Geological
storage
Regional
„User/ Supplier“
Scenario


Countries A1,A2,..Ai
Regional Facilities
Country B
Reprocessing: 3100 tons
Fabrication: 276 tons
Interim Storage Spent fuels UOX-PWR
Spent UOX fuel
SMFR 20x50=1 GWe
12.5 % Pu, 1.9% MA
SMFR fuel
Spent SMFR fuel
Reprocessing: 276 tons
Fabrication: 190 tons
GEN IV fuel
Gen-IV GFR 10 fuel reloads
18.3 % Pu, 2.4% MA
Wastes
Interim storage
Geological storage
Regional „User/ Supplier“ Scenario

- The data of the previous scheme correspond to the following hypothesis:

  - ✓PWR UOX (BU 50GWd/t, 10y cooling) in country B
  - ✓20 SMFRs adapted to Pu+MA fuel, 30y operation in countries A
  - ✓After 30y, the fuels are sent back for reprocessing and used in country B for Gen-IV reactors

- Further analysis, e.g. to establish the rate of penetration of the SMFRs, would need specification of the policy of country B:

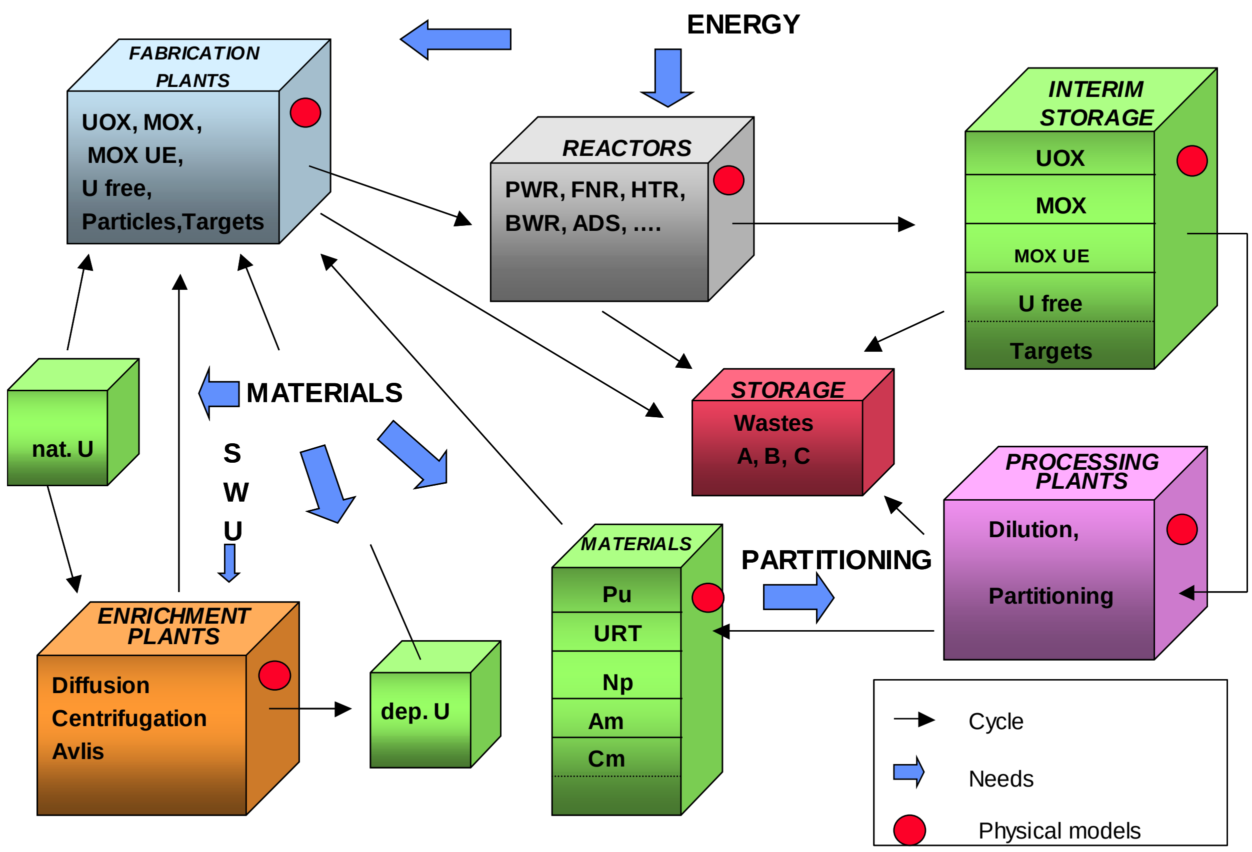
  - ✓If country B stores irradiated UOX fuel (e.g. USA), the 3100t UOX needed will be available at any time.
  - ✓If country B makes reprocessing and use of Pu (e.g. France), it should be worked out how and when the UOX could be „diverted“ and made available.

- The data allow to figure out the size of the reprocessing and fabrication facilities, according to the SMFRs penetration rate foreseen.

- The reprocessing as shown in the scheme, considers not-separated TRU. Other schemes can be envisaged.

A tool for scenario studies : COSI

- Facilities of the fuel cycle: mines, enrichment, fabrication facilities, reactors, reprocessing facilities, stockpiles, waste storage,
- Input data for the simulation: energy demand, fuel and nuclear materials requirements
- Transfers of nuclear materials (thin black arrows),
- Change in isotopic composition of materials using physical modelling (full red circles)



REGIONAL SCENARIO STUDIES ARE NOW EXTENDED TO A WIDER EUROPEAN CONTEXT, IN THE FRAME OF A COORDINATION ACTION OF THE 6th FRAMEWORK PROGRAM OF THE EU (PATEROS)

1) Objectives

A regional approach at the European level should help to outline a roadmap to implement P&T : how to to share facilities and fuel inventories to optimise the use of resources and investments in an enhanced proliferation-resistant environment.

2) Hypotheses concerning the regional scenario:

The scenarios will consider several groups of countries:

- **Group A is in a phase out (or stagnant) scenario for nuclear energy and has to manage his spent fuel, and especially the Plutonium and the minor actinides.**
- **Group B is in a continuation scenario for the nuclear energy and has to optimise his resources in Plutonium for the future deployment of fast reactors or ADS.**
- **Group C, after stagnation, envisages a nuclear "renaissance"**
- **Group D, initially with no NPP, decide to go nuclear**

Different scenarios will be studied and are being defined. Examples being examined:

1- Scenarios which consider the deployment of a group of ADS shared by several countries:

- **The ADS will use the Minor Actinides of the group B and will transmute the TRU of the other groups.**
- **The Plutonium of the group B is mono- or continuously recycled in PWRs.**
- **The main objective of these scenarios is to decrease the stock of spent fuel of countries A and C down to 0 at the end of the century and to stabilize/decrease the MA stocks of group B.**

The results of the study will be:

- **Pace of deployment and the number of ADS necessary to eliminate the stock of spent fuel of group A at the end of the century;**
- **Fuel cycle facilities needed and time horizon for deployment; masses and heat load in a repository.**

2- Scenarios which consider the deployment of fast reactors in group B countries:

Fast reactors are deployed with the Plutonium of all groups of countries and recycle all the minor actinides.

The main objectives of this scenario are:

- **to decrease the stock of spent fuel of countries A and C down to 0 at the end of the century and**
- **to introduce Gen-IV fast reactors in group B, starting e.g. in 2035.**

The results of the study will be:

- **Number and feasibility (e.g. allowable MA content) of fast reactors to be deployed in countries B**
- **Number and characteristics of the fuel cycle facilities;**
- **Masses and heat load in a shared repository.**

3- Scenarios where countries of group C (and/or D) decide, after a certain period of time, to restart nuclear energy with fast reactors which recycle all their own TRU.

Variants can be envisaged, according to the policy of Group B, e.g.

- **Mono-recycling of Pu and successive use of fast reactors or**
- **Use of fast reactors at an early date.**

The spent fuel of the other countries of group A is used to facilitate the deployment of fast reactors in group C.

The results of the scenario study will be:

- **Maximum level of electricity production achievable at equilibrium for the group C. This result will depend on the amount of Plutonium available and on the pace of deployment of the Fast reactors.**
- **Fuel cycle facilities characteristics and parameters related to the repository will be obtained.**

At present , six countries have made available their spent fuel inventories and isotopic compositions (at several dates):

Belgium, France, Germany, Spain, Sweden, Switzerland

The inventory of the countries of Group “A” (Belgium, Germany, Spain, Sweden, Switzerland) will be in ~2020: ~300t Pu and ~35t MA

Scenarios are presently being discussed. Hypotheses on parameters such as energy demand, cooling times etc. and on characteristics such as type of fast reactor and ADS etc., will be agreed shortly.

Preliminary results (mostly obtained with the COSI code) are expected at the end of 2007.

Conclusions

- **Regional approaches to the nuclear fuel cycles have been proposed in various frameworks.**

- **In the case of Europe, it is interesting to develop such scenarios to investigate opportunities for enhanced collaboration, in particular in the perspective of advanced fuel cycles.**

- **First results have been obtained, which confirm the potential interest of regional approaches to the fuel cycle.**

- **More results are expected in the very near future in the frame of a European Coordination Action for a Roadmap to develop P&T (PATEROS).**

- **However, to make these scenarios more realistic, a number of complex institutional (e.g. shared repository) and practical (e.g. material transports) issues should be tackled and discussed in depth.**

Back-up

Scenario 2:

This scenario considers the deployment of fast reactors in Group B countries. These fast reactors are deployed with the Plutonium of the two groups and recycle all the minor actinides.

The main objective of this scenario is to decrease the stock of spent fuel of countries A down to 0 at the end of the century and to introduce Gen-IV fast reactors in group B, starting, e.g., in 2035.