OECD-NEA Task Force on Potential Benefits and Impacts of Advanced Fuel Cycles with Partitioning and Transmutation: Summary of Major Findings

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« For a successful technology, reality must take precedence over public relations, for nature cannot be fooled »

Richard Feyman
(Challenger Commission Report, 1986)

Introduction

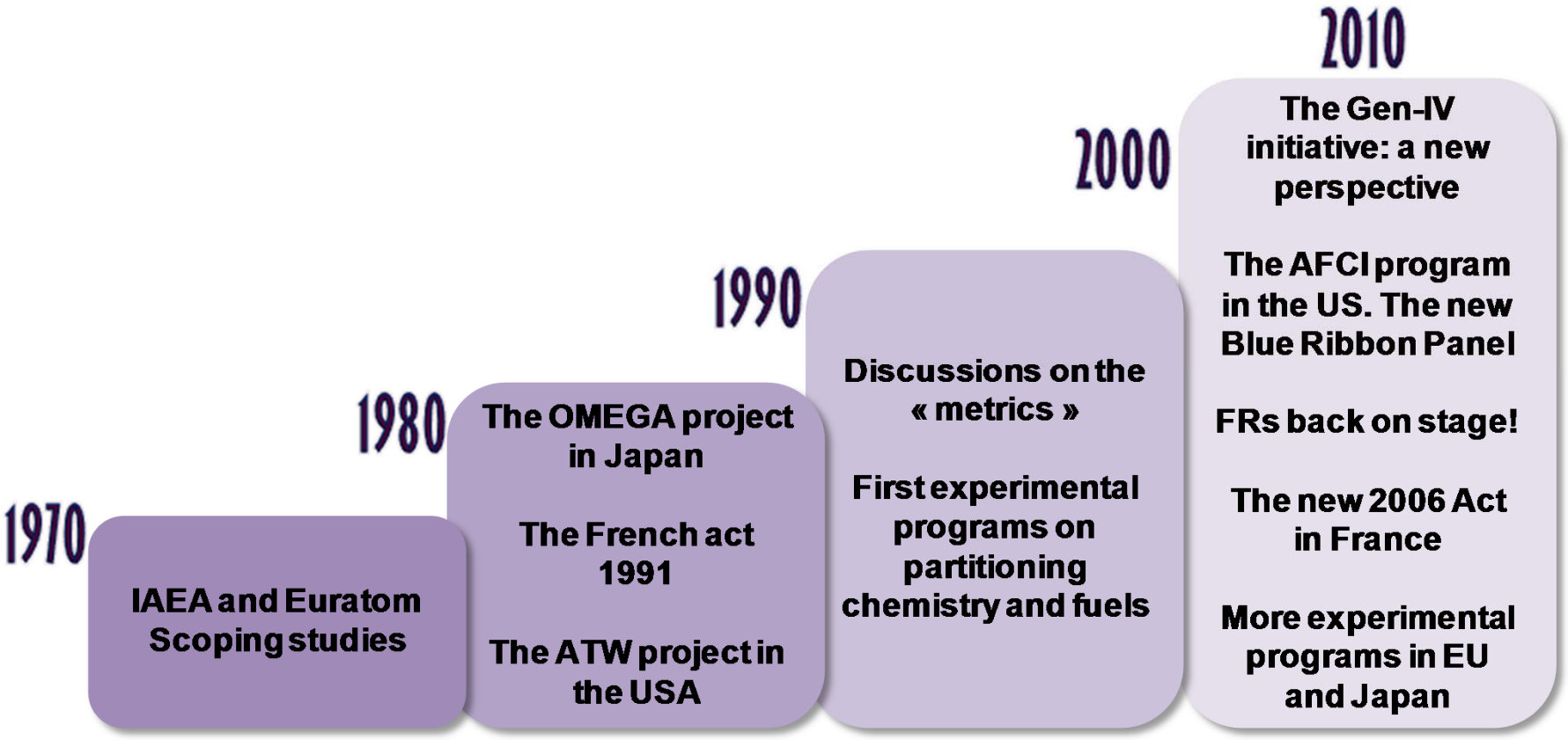
- **Whatever the impact of the recent events on nuclear development policies in different countries, the need for a sound and well accepted waste management remains a major issue**

- **Both technical and societal arguments have to be considered**

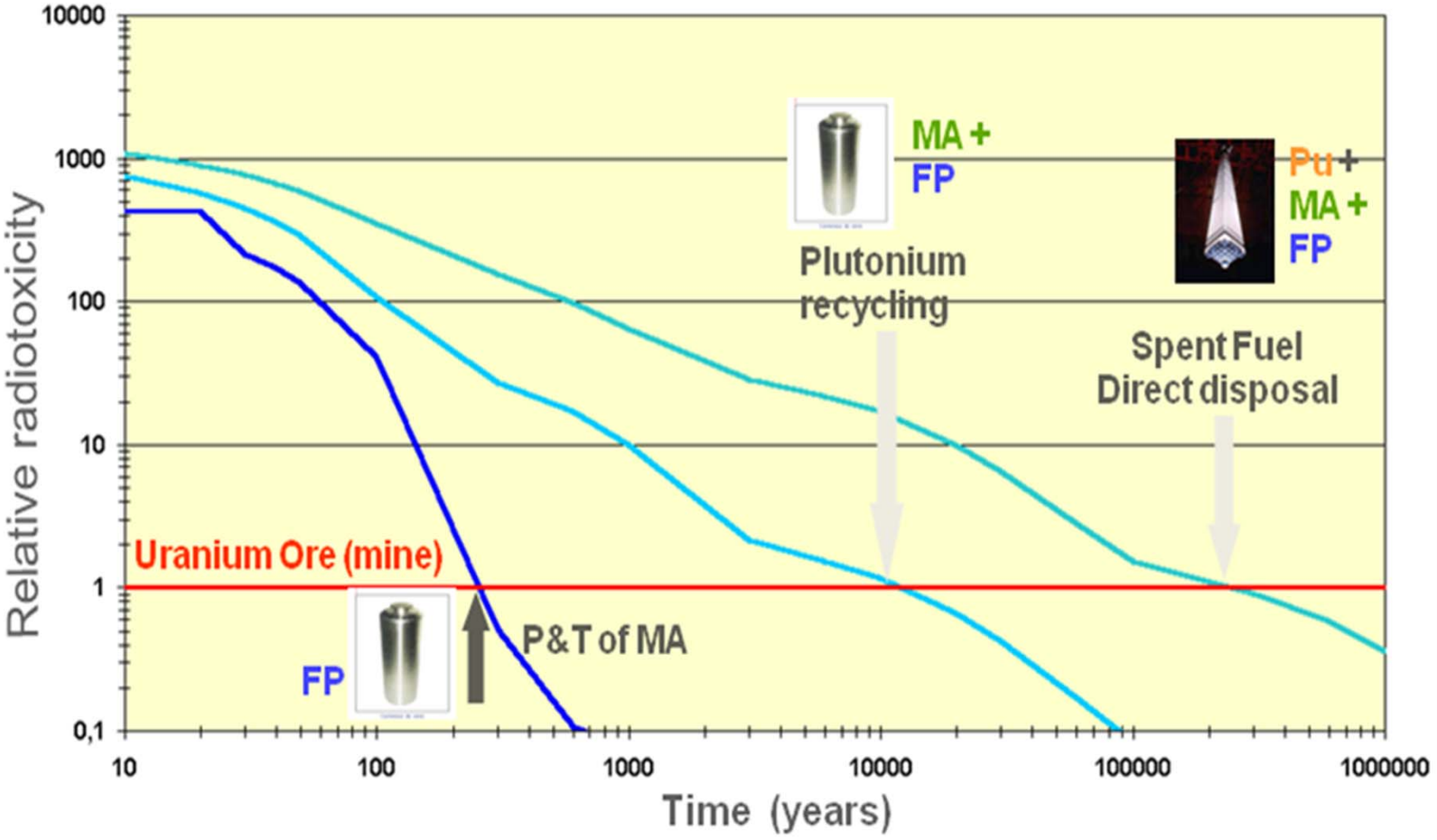
- **In this context, the analysis and consensus building on the potential benefits of Partitioning and Transmutation strategies, is very important.**

- **In fact Partitioning and Transmutation (P&T) of the actinide elements has been considered as a way of reducing the burden on a geologic disposal, since the P&T strategy of recycling actinides allows in principle a combined reduction of the amount of radioactive waste to be stored and the associated residual heat.**

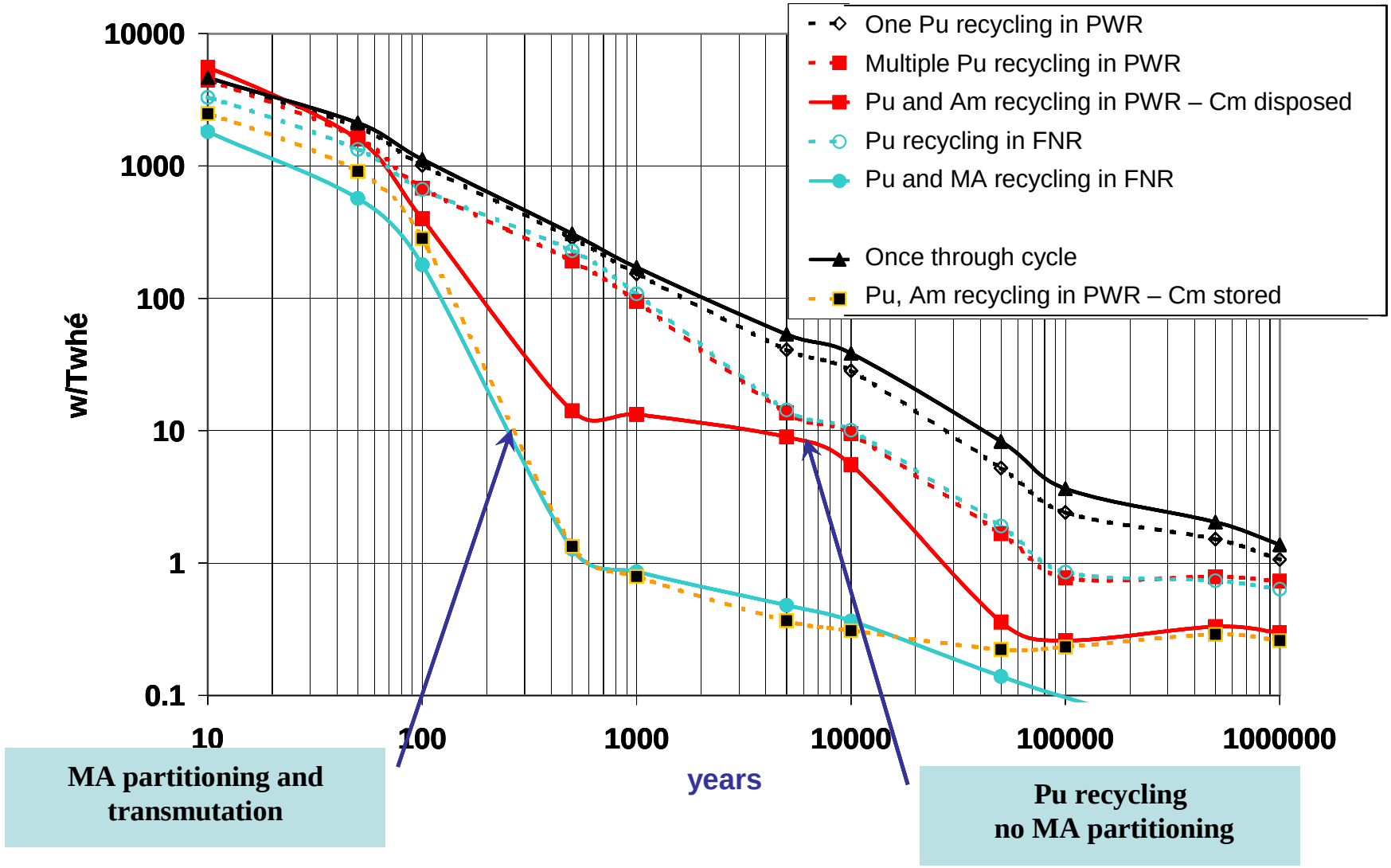
P&T and simulation studies



Evolution with time of P&T focus and studies



Simulation of radiotoxicity reduction vs. time (Ingestion radiotoxicity normalized to natural uranium and decay products as occurs in natural uranium ore).



Simulation of different P&T strategies effect on the evolution of the long term decay heat

The NEA Task Force

The study that has been performed by our Task Force within the Working Party on Scientific Issues of the Fuel Cycle (WPFC) of the OECD NEA Nuclear Science Committee had the objective to **gather and analyse results of different studies performed to assess the potential impact of P&T on different types of repositories in different licensing and regulatory environments.**

Criteria, metrics and impact measures have been analysed and compared, in order to give an objective comparison on the state of the art that can help to shape decisions on different options of future advanced fuel cycles.

A final report of the Task Force is available: http://**www.oecd-nea.org/science/reports/2011/6894-benefits-impacts-advanced-fuel.pdf**

The purpose of this presentation is to summarize the main finding of that study

The consensual outcome of the present assessment reflects for the different expertise and background of the members of the Task Force, spanning from reactor safety and fuel cycle physics to radiochemistry and geologic disposal concepts analysis.

Summary of Past Studies on the Impact of P&T

Past studies including the specific analysis of the possible benefit and impact of P&T have been reviewed and compared in terms of the following criteria:

a) Peak dose rate
b) Radiotoxicity
c) Decay heat
d) Waste form, volume and mass
e) Uncertainty
f) Other aspects such as proliferation and cost.

The comparison among independent studies by different countries and regions in the world, has been crucial to extract the essence of various results and to build a common understandings.

IAEA, “Implications of Partitioning and Transmutation in Radioactive Waste Management”, Technical Report Series No. 435, International Atomic Energy Agency, (2004).

OECD/NEA, “Advanced Nuclear Fuel Cycles and Radioactive Waste Management”, NEA No. 5990, (2006)

W. von Lensa, et al. (ed.), “RED-IMPACT, Impact of Partitioning, Transmutation and Waste Reduction Technologies on the Final Nuclear Waste Disposal: Synthesis Report”, (2007)

J. Marivoet, et al., “Impact of Advanced Fuel Cycle Scenarios on Geological Disposal”, Euradwaste ’08 Conference, (2008).

H. Geckeis, et al., “Impact of Innovative Nuclear Fuel Cycles on Geological Disposal”, Annual Meeting of Nuclear Technology (2008).

R. Wigeland, et al., “Separations and Transmutation Criteria to Improve Utilization of a Geologic Repository”, Nucl. Technol., 154, 95 (2006)

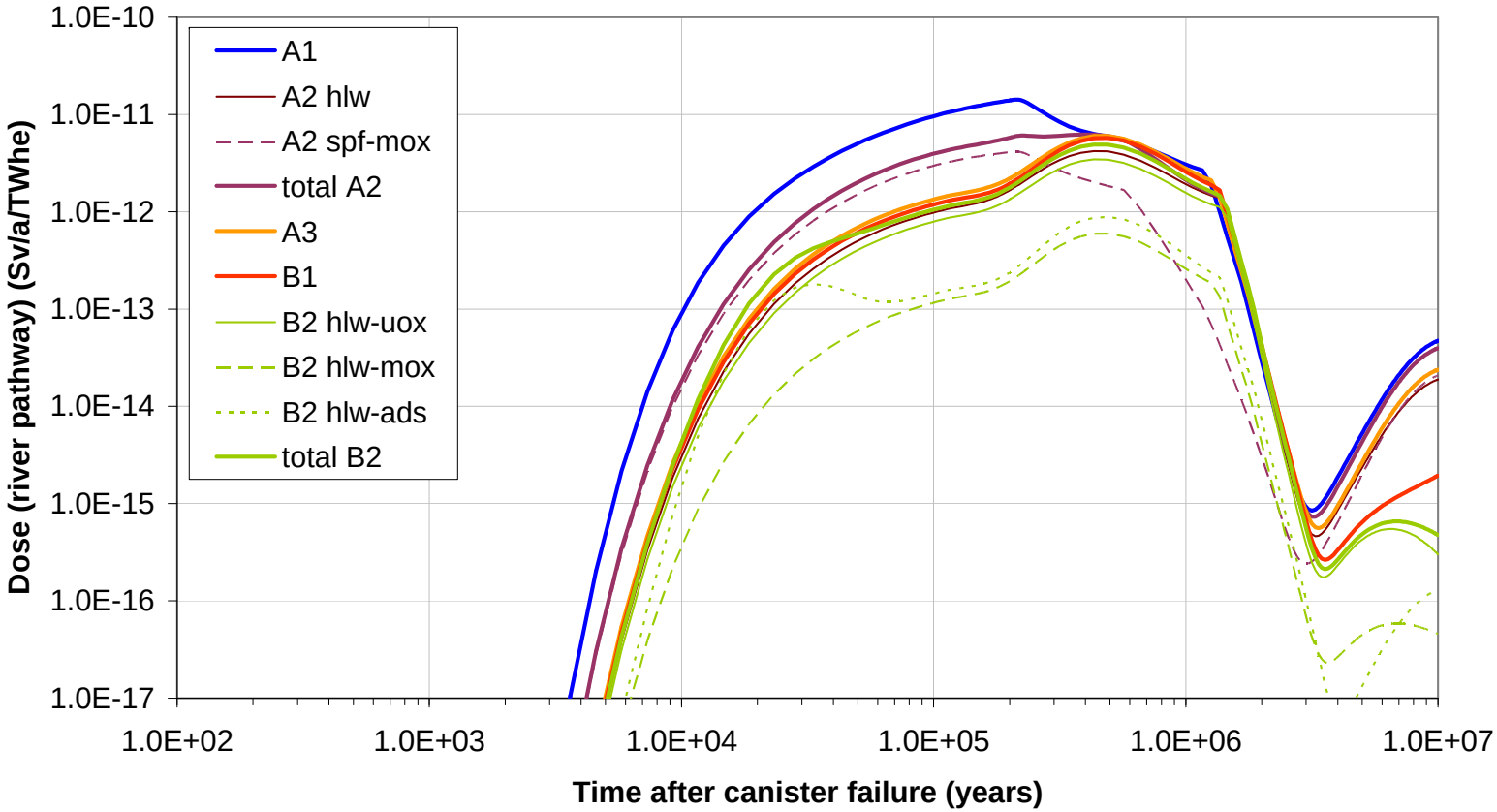
R. Wigeland, et al., “Impact on Geologic Repository Usage from Limited Actinide Recycle in Pressurized Light Water Reactors”, J. Nucl. Sci. Technol., 44(3), 1 (2007).

C. W. Forsberg, “Rethinking High-level Waste Disposal: Separate Disposal of High-heat Radionuclides (^{90}Sr and ^{137}Cs) ”, Nucl. Technol., 131, 252 (2000).

K. Nishihara, et al., “Impact of Partitioning and Transmutation on LWR High-Level Waste Disposal”, J. Nucl. Sci. Technol., 45(1), 84 (2008)

H. Oigawa, et al., “Partitioning and Transmutation Technology in Japan and its Benefit on High-level Waste Management”, Proc. of GLOBAL2007, Int. Conf. on Advanced Nuclear Fuel Cycles and Systems, Global 2007, Boise, Idaho, September 9-13, 2007.

H. Oigawa, et al., “Concept of Waste Management and Geological Disposal Incorporating Partitioning and Transmutation Technology”, Proc. OECD/NEA 10th Information Exchange Meeting on Actinide and Fission Product Partitioning and Transmutation, 6-10 October 2008, Mito, Japan, (2008).



Impact of the various fuel cycles on the dose calculated for the normal evolution scenario:

- between 7,000 and 250,000 years: impact of direct disposal or reprocessing on the iodine content (doses are mainly due to I-129) of the waste

- between 250,000 and 2 M years: the peak is mainly due to Se-79 and Sn-126

- after 3 M years: doses due to actinides, which are significantly lower in the case of fuel cycles with full recycling of the actinides.

Ref. W. von Lensa, et al. (ed.), "RED-IMPACT, Impact of Partitioning, Transmutation and Waste Reduction Technologies on the Final Nuclear Waste Disposal: Synthesis Report", (2007)

Role of ADS in Advanced Fuel Cycle:
Innovative Waste Management. Repository Area

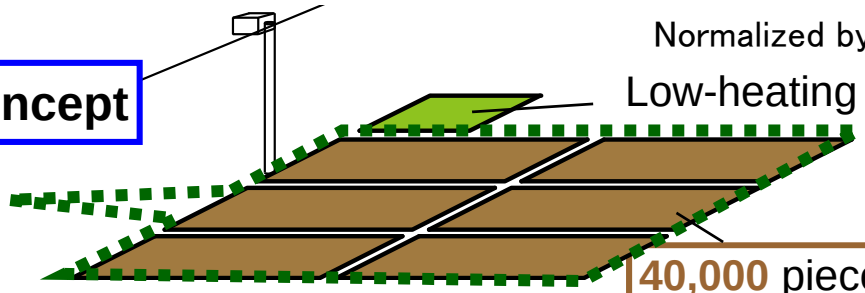
Normalized by 32,000tHM of 45GWd/t spent fuel

Low-heating wastes (0.13km^2)

CT: Cooling time before disposal

Conventional Concept

1.8 km^2

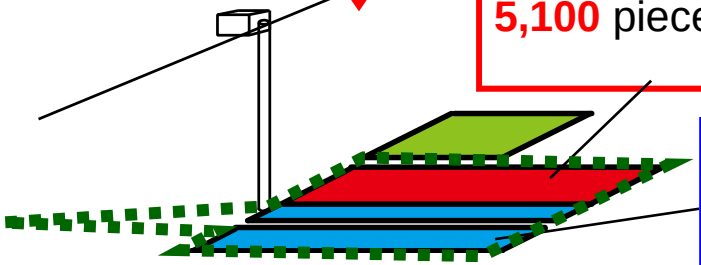


(Vertical emplacement in crystalline rock)

40,000 pieces of **glass waste forms** (1.8km^2)
(CT: **50** y)

MA transmutation
+
FP Partitioning

0.41 km^2

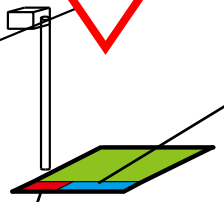


5,100 pieces of **Sr-Cs** calcined forms (0.23km^2)
(CT: **130** y)

8,300 pieces of **highly-loaded glass** waste forms (0.18km^2)
(CT: **5** y)

MA transmutation
+
FP Partitioning
+
Long-term storage of Sr+Cs

0.015 km^2



8,300 pieces of **highly-loaded glass** waste forms (0.01km^2)
(CT: **45** y)

5,100 pieces of **Sr-Cs** calcined forms (0.005km^2)
(CT: **320** y)

Ref. : K. Nishihara, et al., "Impact of Partitioning and Transmutation on LWR High-level Waste Disposal", J. Nucl. Sci. Technol., 45(1), 84-97 (2008).

Major Findings of the Task Force

- The analysis performed has indicated that most recent studies have demonstrated that ***the impact of P&T on geological disposal concepts can be significant even if not overwhelmingly high.***

- In fact, ***by reducing waste heat production a more efficient utilization of repository mines is likely*****.** In practice, the reduction of the thermal output of the High Level Wastes by a factor of ~3 can reduce the needed repository gallery length by a factor ~3 and the repository footprint up to a factor 9.

- The reduction of masses, volumes and heat allows a very favorable ***flexibility*** in any storage strategy

- Moreover, even if radionuclide release from the waste to the environment and related potential doses to the population are not significantly reduced by P&T since mostly dominated by some long lived fission products, ***it is important to point out that a clear reduction of the actinide inventory in the Highly Active Waste (HAW) reduces risks arising from less probable evolutions of a repository, i.e. increase of actinide mobility in certain geochemical situations and radiological impact by human intrusion.***

- One significant effect of P&T is that the inventory of the emplaced materials is much lower on an energy generated basis for the actinide elements.

  This can have ***the effect of making the uncertainty about repository performance less important.***

  In fact, the P&T can reduce the importance of uncertainties both in normal evolution and in particular those related to hypothetical disruptive scenarios that can bring man in direct contact with the disposed waste, since these scenarios are affected by the hazard (radiotoxicity) and not so much by the geology, and P&T of the actinides does reduce the hazard of the emplaced materials.

- By introducing P&T in the fuel cycle, the mass of actinides can be significantly reduced in the HLW, and may be possible to reduce HLW volume and mass (while long-lived low- and intermediate-waste could sometimes increase).

  The introduction of P&T could increase the options for optimised waste forms.

  For example, as for the vitrified waste, the density of the waste elements in the glass matrix might be increased e.g. because of the reduced heat source.

- ***Of the P&T impact studies examined by the Task Force, none attempts a comprehensive assessment on the impact on proliferation resistance.***

  Evaluation Methodologies for proliferation resistance and physical protections have been developed but to date only very preliminary attempts have been made to apply them to specific advanced fuel cycle strategies.

- ***The radiotoxicity has been used as the index to demonstrate the effect of MA transmutation. The Task Force did somewhat de-emphasize this parameter***

  All the previous studies assumed 99 – 99.9% recovery of TRU, and eventually about two orders of magnitude reduction of radiotoxic inventory were foreseen after several hundred years and later.

  This index is also used to emphasise the effect of shortening the time period needed to decay below a reference level.
  As a reference level, the radiotoxicity of the initial natural uranium in equilibrium with its decay products has been used.

  In fact, TRU transmutation shortens the time period needed to reduce the radiotoxicity to the reference level to several hundred years, though more than 100,000 years will be necessary in the case of direct disposal.

However, it should be recognized that radiotoxicity alone may not be the essential indicator of the effect of actinide partitioning and transmutation on the estimated dose rate for some repository concepts, since both radiotoxicity and exposure pathway characteristics are needed to evaluate repository performance.

Summary

- A major outcome is the recognition that one significant effect of P&T is that the ***inventory of the emplaced materials is much lower*** on an energy generated basis for the actinide elements that can have an impact on the repository, since by reducing waste heat production a ***more efficient utilization of the repository space is expected.***

- Moreover the inventory reduction can make the ***uncertainty*** about repository performance less important both in normal evolution and in particular in case of hypothetical disruptive scenarios that can bring man in direct contact with the disposed waste, since the P&T of the actinides does reduce the hazard of the emplaced materials.

- It is also pointed out that, while P&T will never replace the need for a deep geologic repository, P&T could significantly improve the ***public perception*** of the ability to effectively manage radioactive wastes by largely reducing the TRU waste masses to be stored and, consequently, to improve the ***public acceptance*** of a geologic repository. Both issues are important to future sustainability of nuclear power.

- ***Major nuclear countries show a cautious attitude about P&T and favour further studies, but it is recognized that P&T provides a much needed flexibility in front of possible storage options, regulatory evolutions and the handling of uncertainties.***

- **A final lesson learned:**

If a man begins with certainties, he shall end in doubts; but if he will be content to begin with doubts, he shall end in certainties

Francis Bacon
(The Advancement of Learning, 1605)