Assessment of proliferation risk related to various fuel cycle scenarios in Finland

Pauli Juutilainen • Silja Häkkinen

VTT Technical Research Centre of Finland

Introduction / background

The COSI6 code, developed by CEA (France), has been used to simulate hypothetical transition scenarios from thermal to fast reactors in Finland. The aim has been to determine the effect of partitioning and transmutation (P&T) technologies on the transuranic inventories and the consequent increase in the final repository capacity. These simulations were extended into the field of proliferation resistance (PR) evaluations in the most recent calculations. The Charlton's method was used for a preliminary PR analysis for the Finnish case as far as it was compatible with COSI.

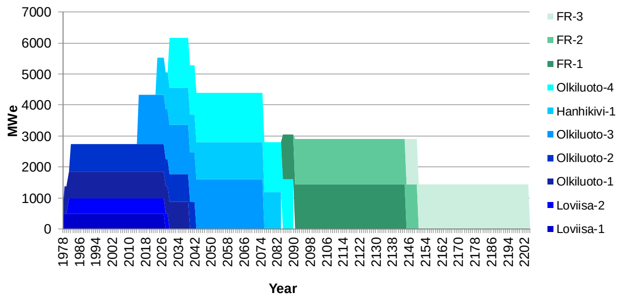

Figure 1. The nuclear power generating capacity in Finland as modelled in COSI6 simulations.

Simulated scenarios

- LWR reference: the currently operating fleet and the units under construction and consideration.
- Pu recycling: after the closure of all LWRs, 2 sodium-cooled fast reactors (SFR, á 1450 MWe) operate for 60 years and 1 similar after them. Nuclear phase-out thereafter.
- MOX + Pu recycling: as Pu recycling, but one of the LWRs is partly fuelled with MOX.
- MA recycling: as Pu recycling, but also the minor actinides are recycled homogeneously with plutonium.

Proliferation resistance and Charlton's method

Charlton's method [1], based on the multi-attribute utility analysis (MAUA), is one of the attempts to quantify proliferation resistance related to various fuel cycle scenarios. It gives the PR value for process *i* as a weighted sum of utility functions:

$$PR_i = \sum_{j=1}^{J=14} w_j u_j(x_{ij})$$

where w_j is the weight factor for attribute j, u_j is the utility function for attribute j and x_{ij} the input value of the utility function for attribute j in process i. In the present study 4 out of 14 attributes were taken into consideration. They were:

- Heating rate of plutonium
- Weight fraction of even plutonium isotopes
- Fissile material concentration, expressed in significant quantities per metric ton (SQ/t)
- Inventory of fissile material (in SQs) at each facility; however, this would score zero PR essentially at every process step of our model, so it was ignored.

[1] W. S. Charlton et al., "*Proliferation Resistance Assessment Methodology for Nuclear Fuel Cycles*" Nuclear Technology, **157**, pp. 143-156

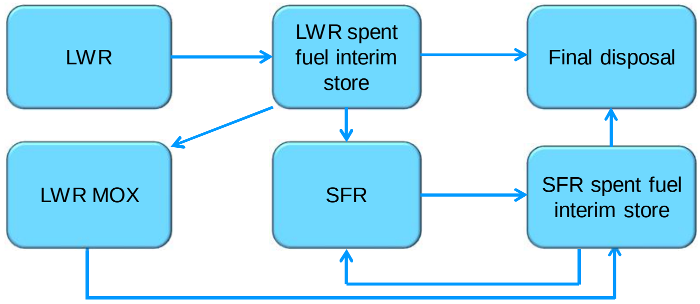

***Figure 2.** The fuel cycles of the simulations. The links between the boxes represent the process steps i, for which the PR_i values were calculated. Spent fuel reprocessing and fuel fabrication were ignored, hence practically included in SFR and LWR MOX boxes.*

Results

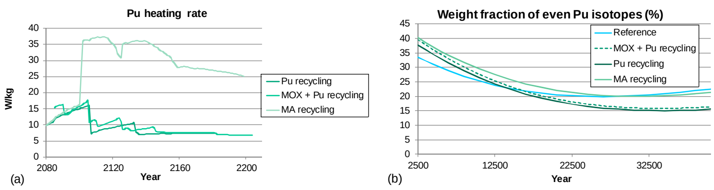

***Figure 3**. (a) The heating rate of plutonium in fresh FR fuel. (b) Long-term changes in plutonium isotope distribution in the repository.*

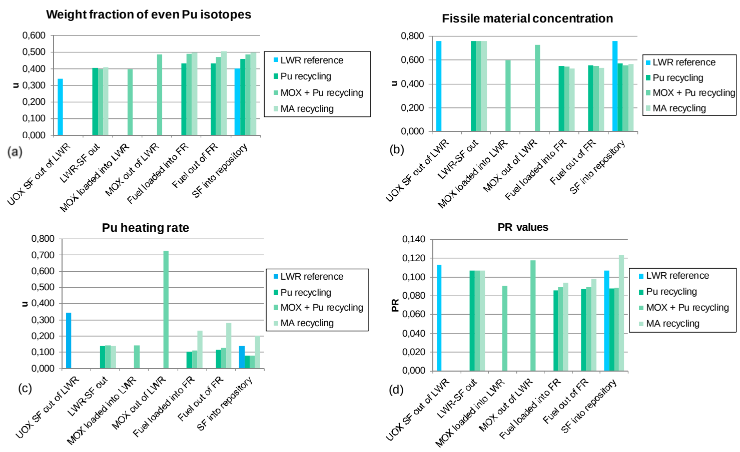

***Figure 4.** (a)-(c) The utility function values for the simulated scenarios at various process steps, or arrows in Fig.2. The attributes are labelled in the chart title of each figure. (d) The proliferation resistance values calculated from the utility functions of the respective process step and scenario.*

Conclusions

The rough analysis brought some quantity to the changes in the proliferation resistance features of the nuclear material recycled in various P&T scenarios. Many important attributes were left outside the study. Some of them would be relatively easy to add into consideration in further studies. For example, the impact of material form and material inventories in realistic-size on-ground stores could be modelled. On the other hand, some attributes, such as the radiation dose, would be rather tedious with the current functionalities of COSI6. The safeguard-related issues would be topical when there are more concrete plans about the system.

Contacts

Pauli Juutilainen
Tel. +358 40 743 0228
pauli.juutilainen@vtt.fi

Silja Häkkinen
Tel. +358 40 023 6898
silja.hakkinen@vtt.fi