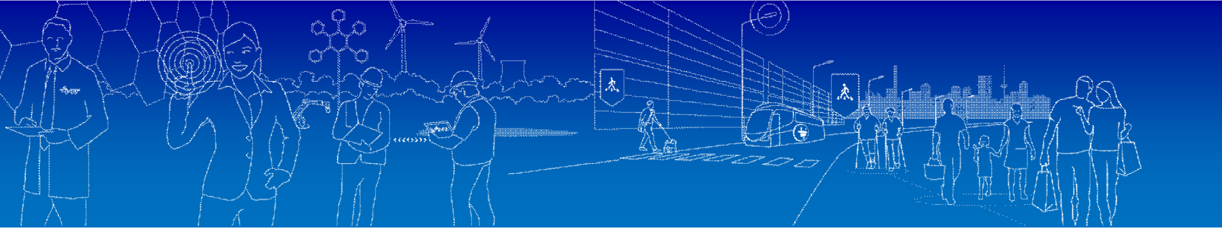

TECHNOLOGY FOR BUSINESS

Advanced fuel cycles – scenario and inventory analysis (KOSKI)

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Overview of KOSKI

The purpose of KOSKI project is to develop and maintain domestic know-how on fuel cycle solutions and computational tools. The advanced fuel cycles studied in the project reduce the amount of high level nuclear waste, decay heat and the overall radioactivity of spent nuclear fuel. This is achieved by transmutation of long lived heat generating actinides such as plutonium and the minor actinides (americium, curium and neptunium).

During the first half of the KYT2018 programme, KOSKI activities have been divided in two research topics.

1. Nuclear fuel cycle scenario analysis

Nuclear fuel cycle scenario codes are capable of modelling the entire fuel cycle. At VTT, two scenario codes have been used which are presented in table 1.

Table 1. Characteristics of scenario codes used at VTT.

	COSI6	SITON
Developed by	CEA (France)	MTA EK and BME NTI (Hungary)
Used at VTT	2011 – 2016	2015 →
Positive features	One of the most advanced fuel cycle codes available	Open source code No licence fee
Negative features	High licence fee Closed source code	Far less extensive than COSI

SITON was first deployed at VTT in 2015 by comparing SITON results to COSI in a direct disposal scenario involving LWR reactors. The current Finnish nuclear fleet was modelled supplemented by Olkiluoto 3, Olkiluoto 4 and Hanhikivi 1. The plutonium and minor actinide inventories calculated by COSI and SITON were compared. Some results are presented in figures 1 and 2.

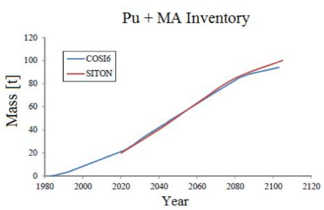

Figure 1. Total mass of plutonium and minor actinides during the simulation.

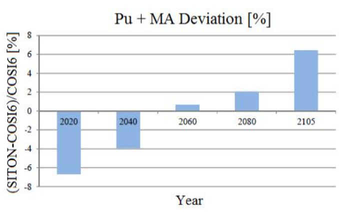

Figure 2. The difference in % between the total mass of plutonium and minor actinides calculated by COSI6 and SITON.

In 2016 the work was continued by calculating the spent fuel inventory with COSI6 in various scenarios using different combinations of U-235 enrichment and fuel burnup. The purpose was to create reference data for future validation of SITON. Two basic scenarios were modelled:

1. Three EPR reactors with open fuel cycle
2. Two SFR reactors with closed fuel cycle employed after the EPRs.

Some results are presented in figures 3 and 4.

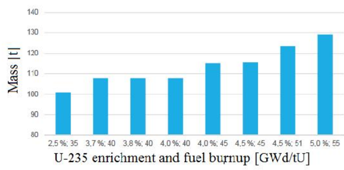

Figure 3. Total mass of plutonium and minor actinides after 100 years in 3 EPR reactors (open fuel cycle).

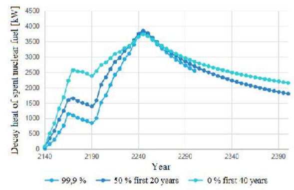

Figure 4. Decay heat of spent nuclear fuel after the employment of SFR reactors and closed fuel cycle. The percentages on the horizontal axis refer to different minor actinide separation efficiencies. The reference is 99,9 percent separation efficiency during the whole simulation.

2. Gamma-dose calculations and proliferation resistance of spent nuclear fuel assemblies

Spent nuclear fuel (SNF) can be attractive to terrorists as material for an atom bomb or a dirty bomb. However, the radioactivity of SNF protects it from misuse. NRC and IAEA consider the "self protecting" dose rate to be 1 Sv/h at 1 m from the fuel assembly. OECD/NEA Expert group AFCS has been calculating a benchmark in order to ensure sufficient self protection of SNF and verify and validate computational systems. VTT has participated in the benchmark using VTT's own Serpent code. Some results are presented in figure 5 and table 2.

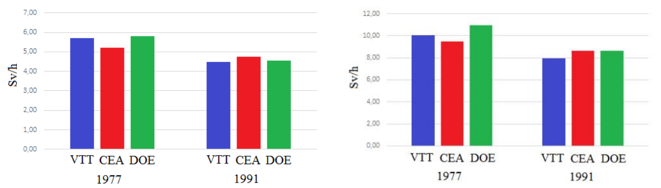

Figure 5. Gamma dose rate from UOX (left) and MOX (right) assemblies after 30 years of cooling. The numbers 1977 and 1991 refer to ANSI conversion factors used to convert the photon flux into dose rate.

Table 2. Gamma dose rate from UOX and MOX assemblies after 3,7 years of cooling. The difference refers to the relative difference between the VTT result and the average result of all participants. The somewhat large differences are mainly related to brehmstrahlung from beta decay.

Conversion factor	UOX [Sv/h]	Diff. To others UOX [%]	MOX [Sv/h]	Diff. To others MOX [%]
1977	29	-8	57	-13
1991	23	-12	47	-11

Future work

- In the future VTT will participate in the development work of SITON in co-operation with the Hungarian developers.
- The gamma-dose rate calculations will be continued with code-to-experiment comparisons.

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