Burnup Credit in Canisters for Final Disposal of Spent Nuclear Fuel

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Swedish nuclear programme

- In Sweden there are presently 10 reactors in operation

- 7 BWR
- 3 PWR
- 2 BWR-plants have been shut down due to government decision.

- Assuming 50-60 years operation time for the reactors this programme will produce around 48000 BWR-assemblies and around 6100 PWR-assemblies.

SKB

- Swedish Nuclear Fuel and Waste Management Co is managing the spent nuclear fuel in Sweden

- The system consists of
  - *Transportation system*
  - *Interim storage facility* (CLAB)

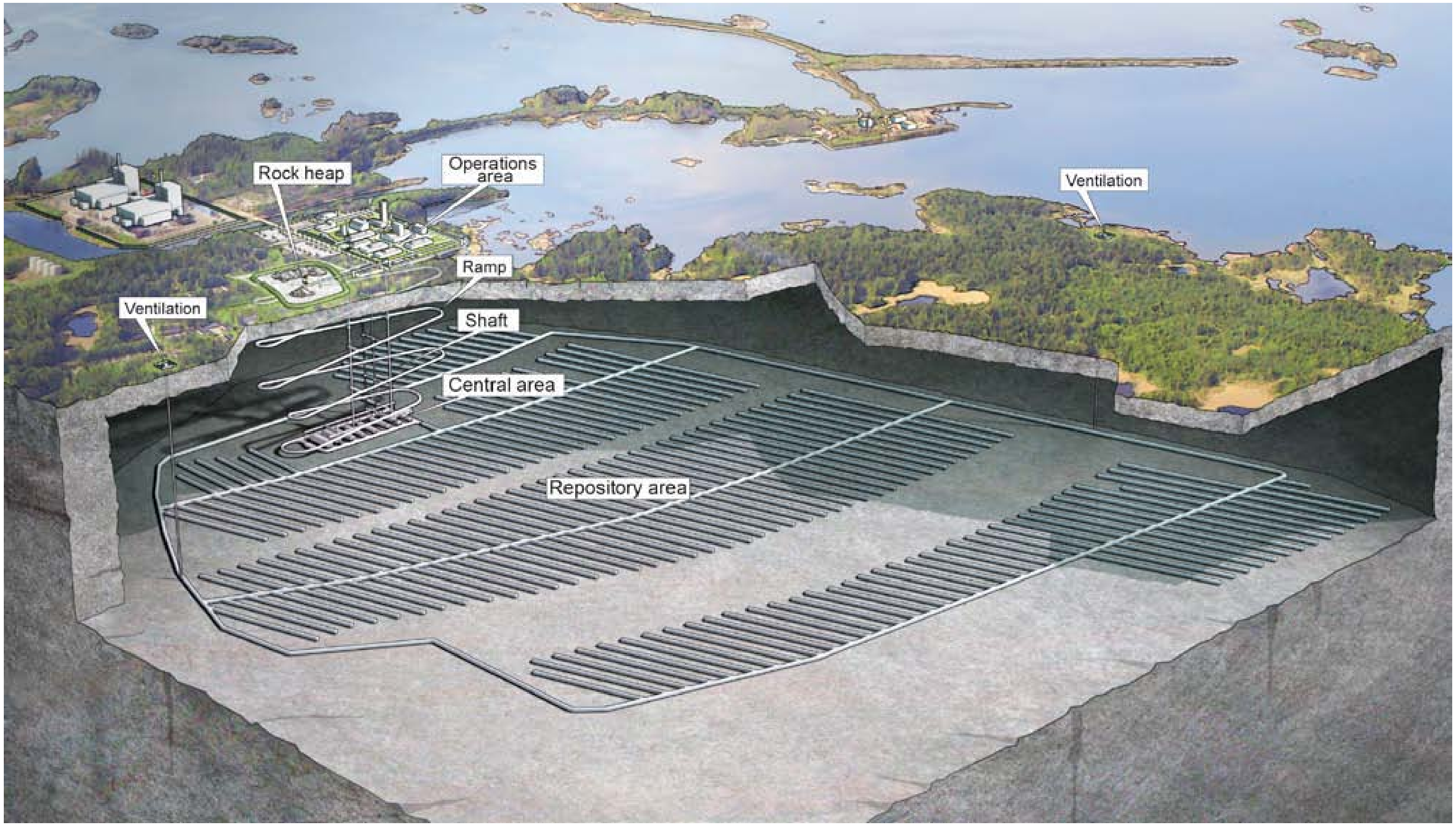
- There are plans for
  - *Encapsulation plant*
  - *Deep repository*

Canister

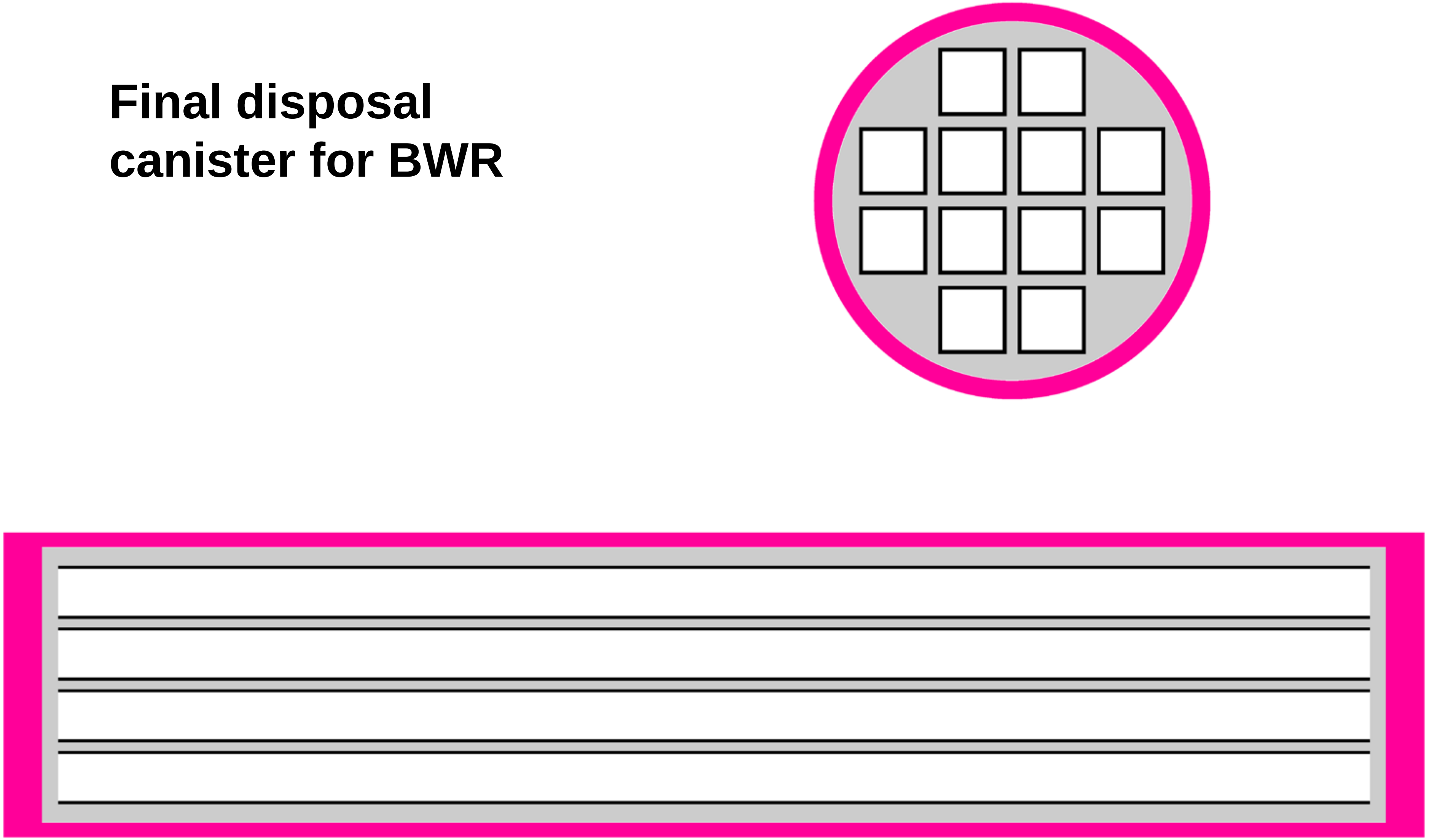
Copper shell	7,400 kg
Insert	13,600 kg
Fuel	3,600 kg

Total weight: 24,600 kg

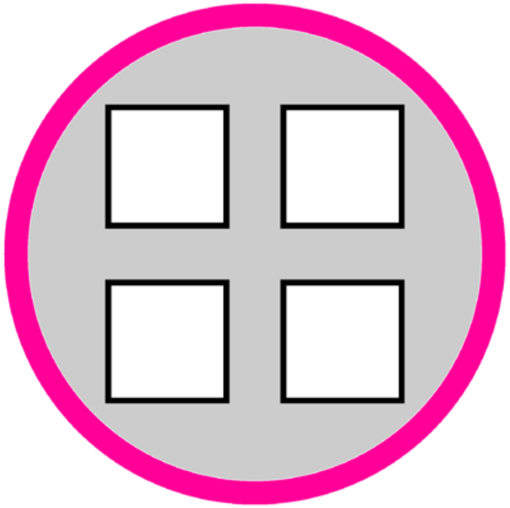
Deep repository

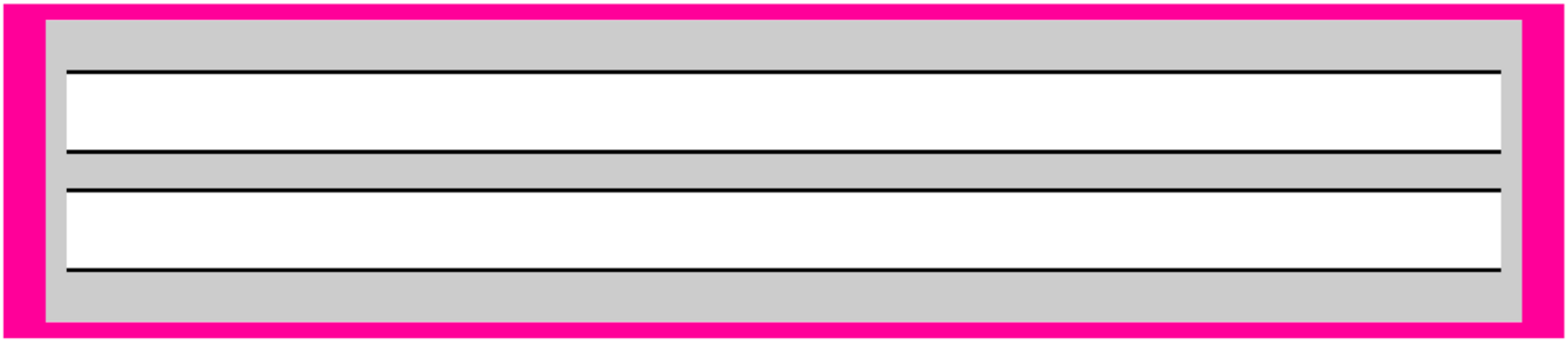


Final disposal canister for BWR



Final disposal canister for PWR





Requirements

- All fuel designs
- Enrichments up to 5 % U235.

Calculations for fresh fuel

k_{eff} for the for 5 % enriched fresh fuel in canisters:

- PWR: $k_{eff} \pm \sigma = 1.1082 \pm 0.0005$
- BWR: $k_{eff} \pm \sigma = 1.0188 \pm 0.0005$

- Burnup credit is needed

Burnup credit for final disposal canister

- Calculations were performed using Scale 5.1
- Depletion calculations were performed using SAS2
- Criticality calculations were performed using Scale CSAS25 and Starbucs sequences . Scale 44 – group (ENDF/B-V) library was used.

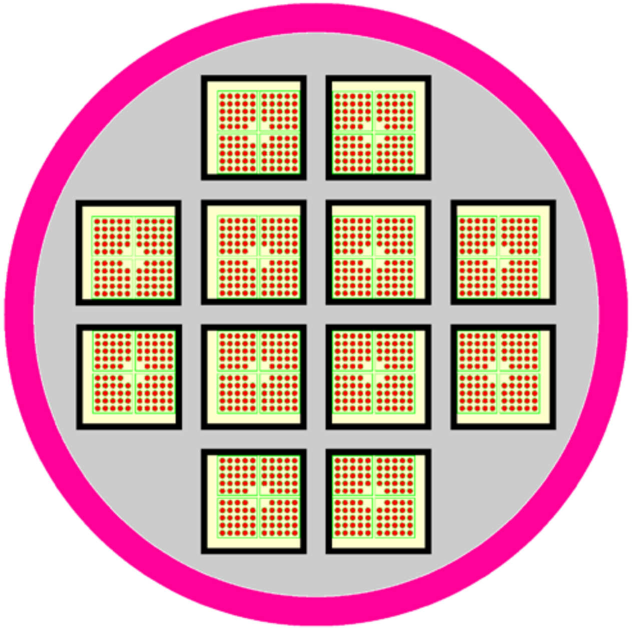
Reference fuel types

- BWR: Svea96 Optima 3

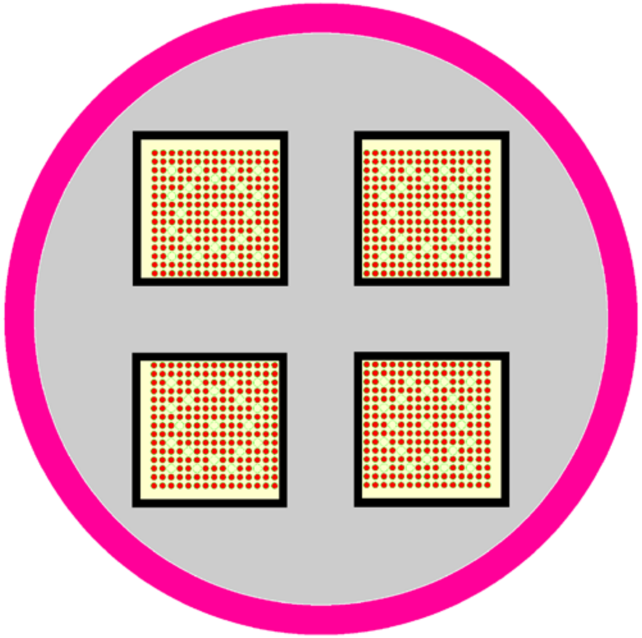
- PWR: 15x15 AFA3G

Models

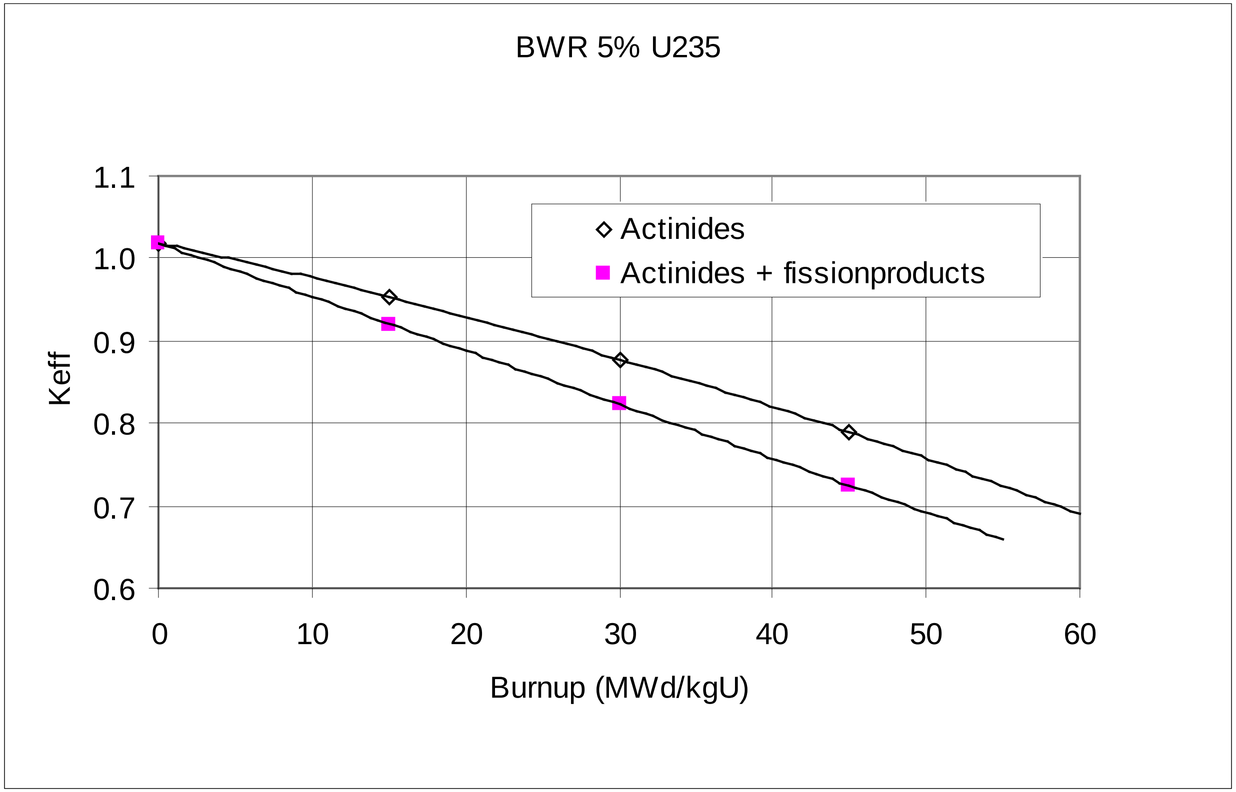
BWR



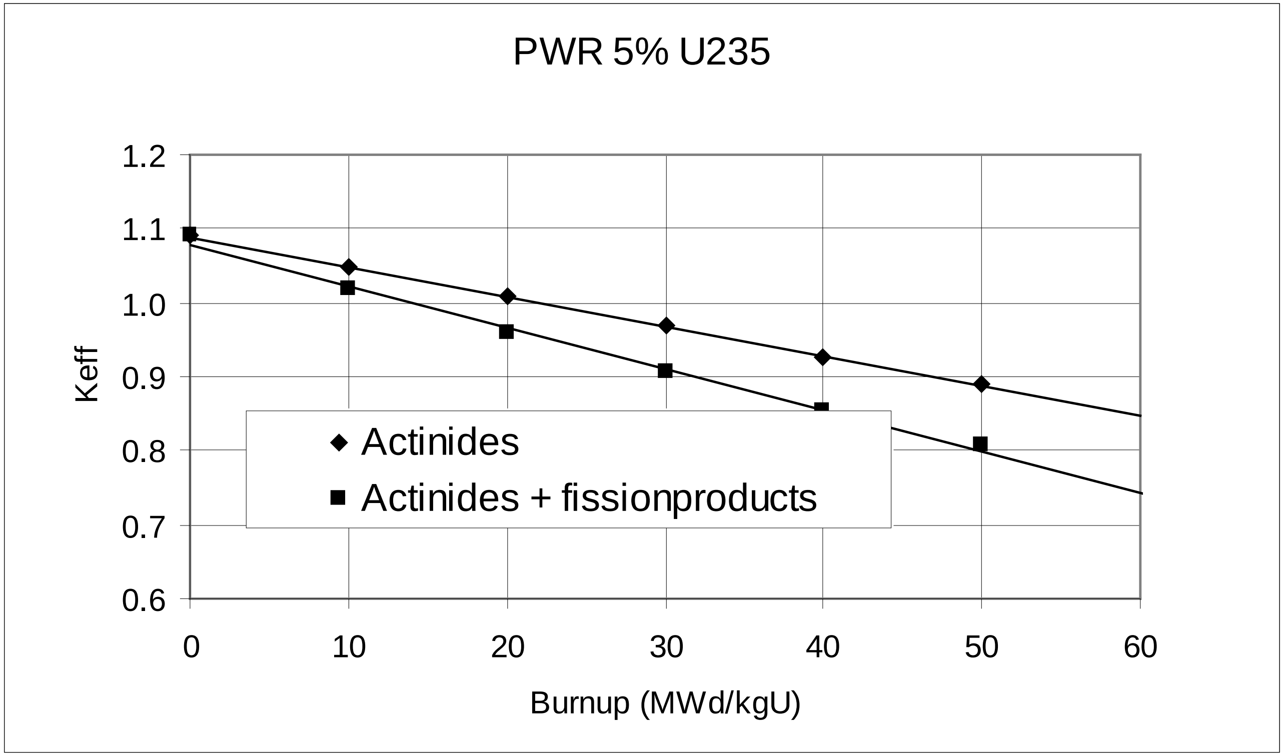
PWR



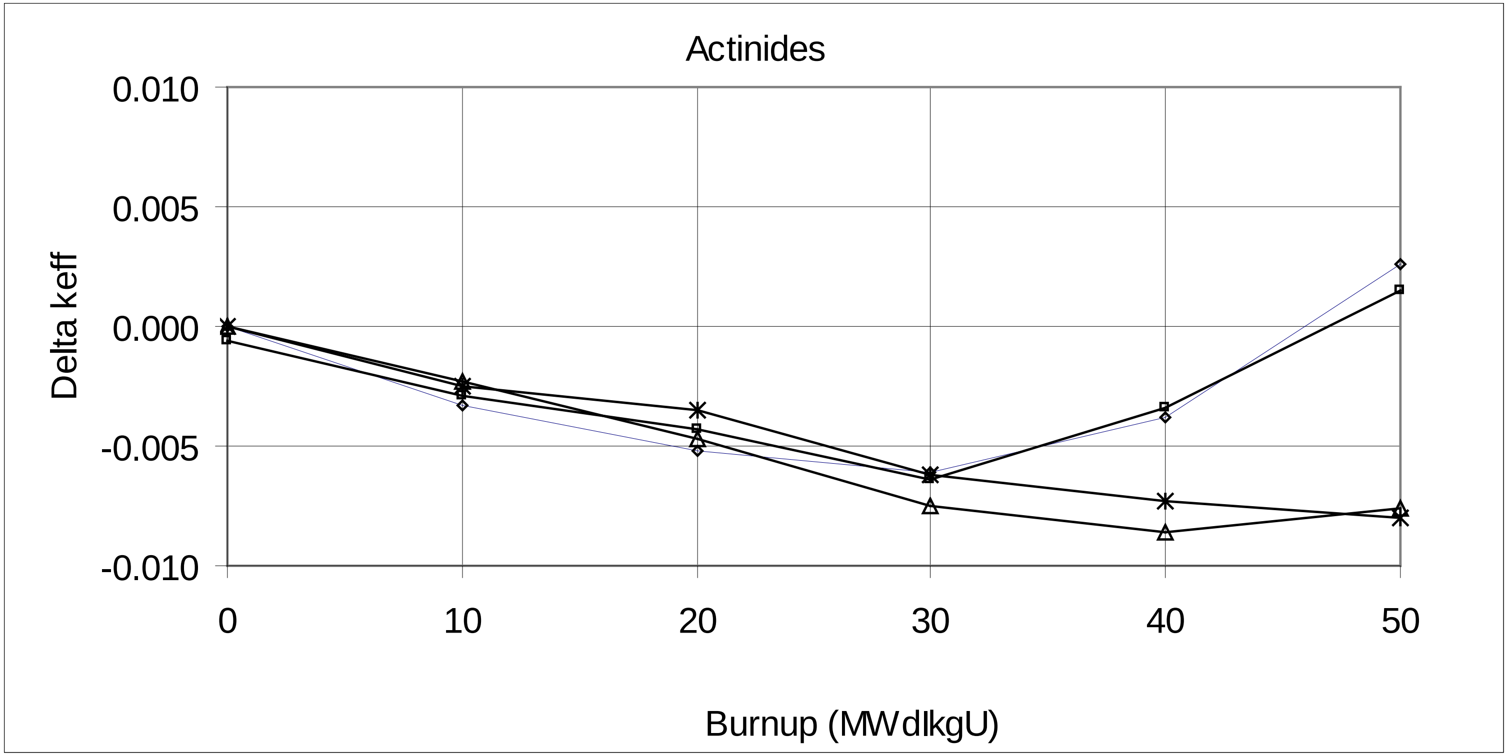
Burnup curves for BWR



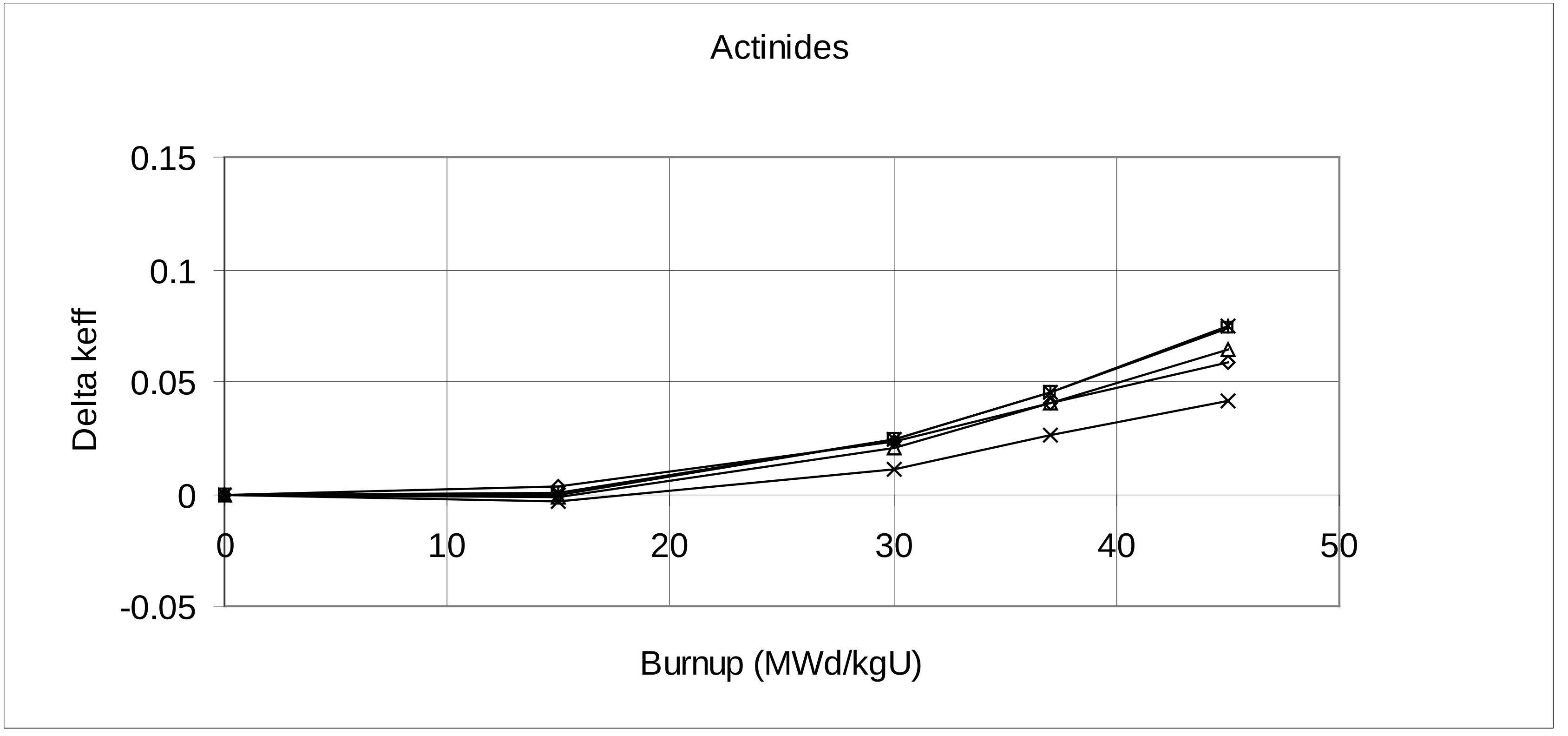
Burnup curves for PWR



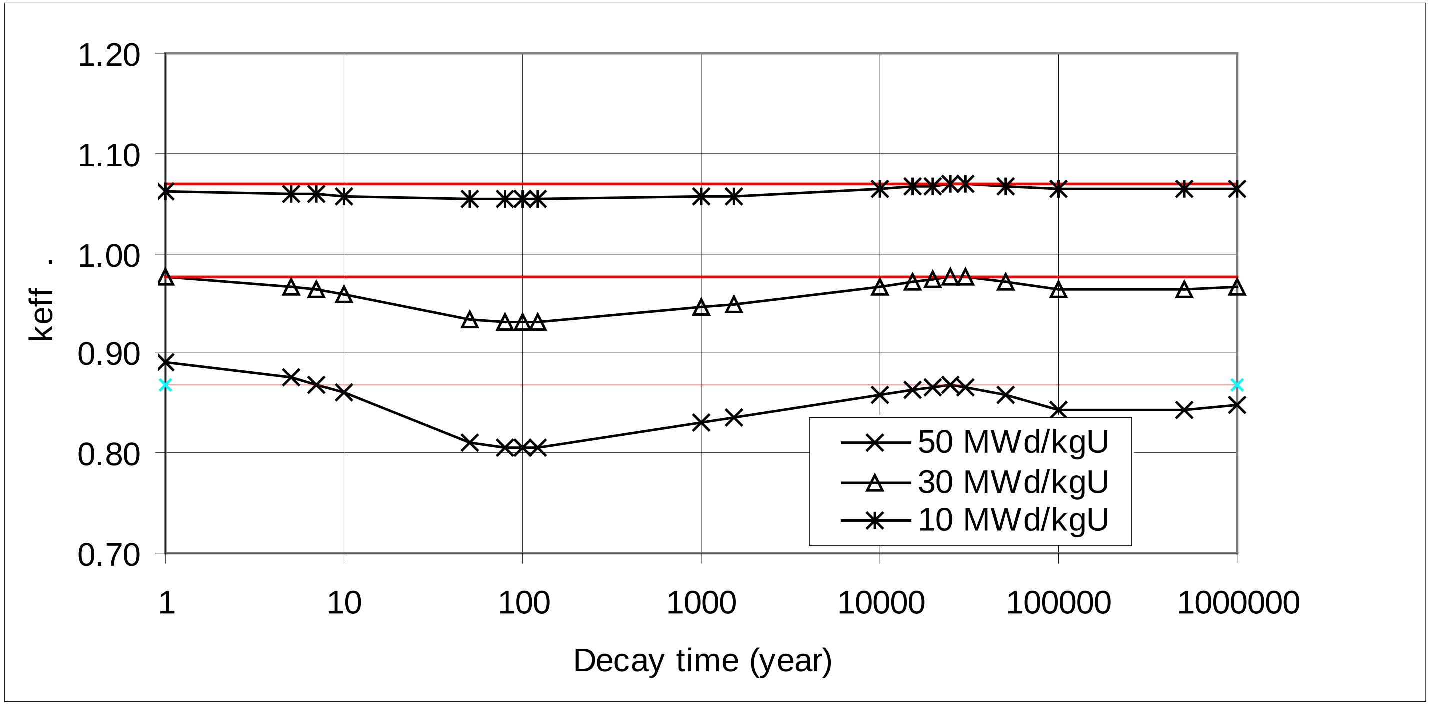
End effect PWR



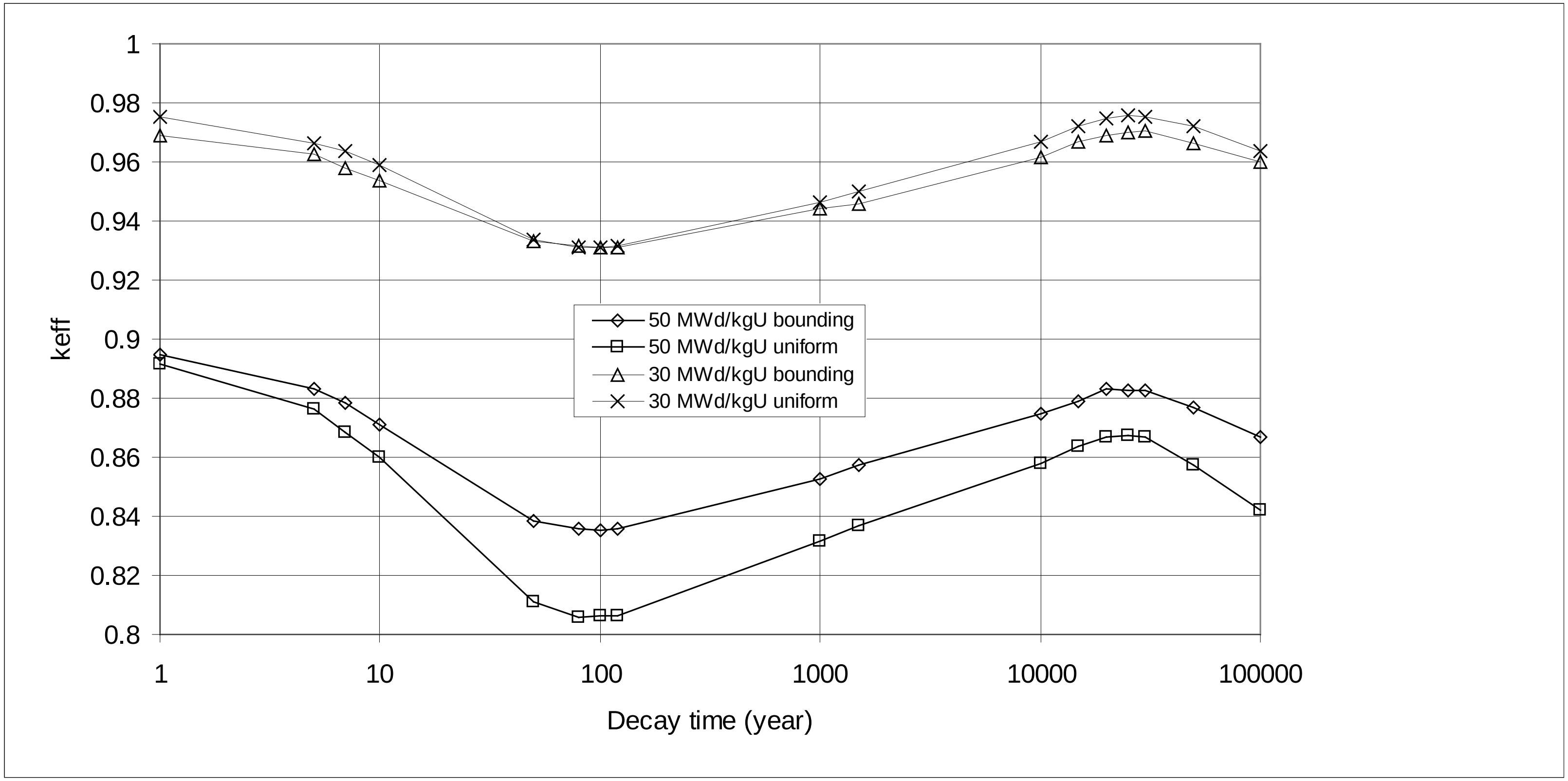
End effect BWR



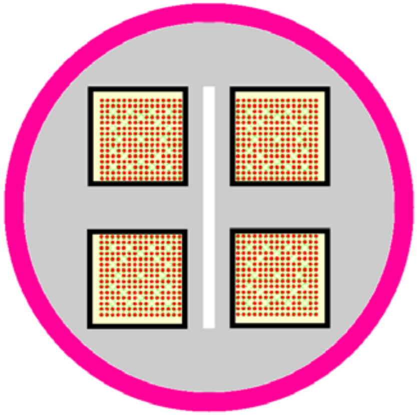
Long term reactivity change

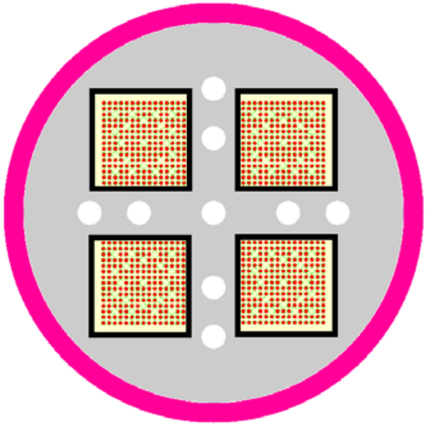


Long term reactivity change, check of axial BU-distibution



Defects in canister

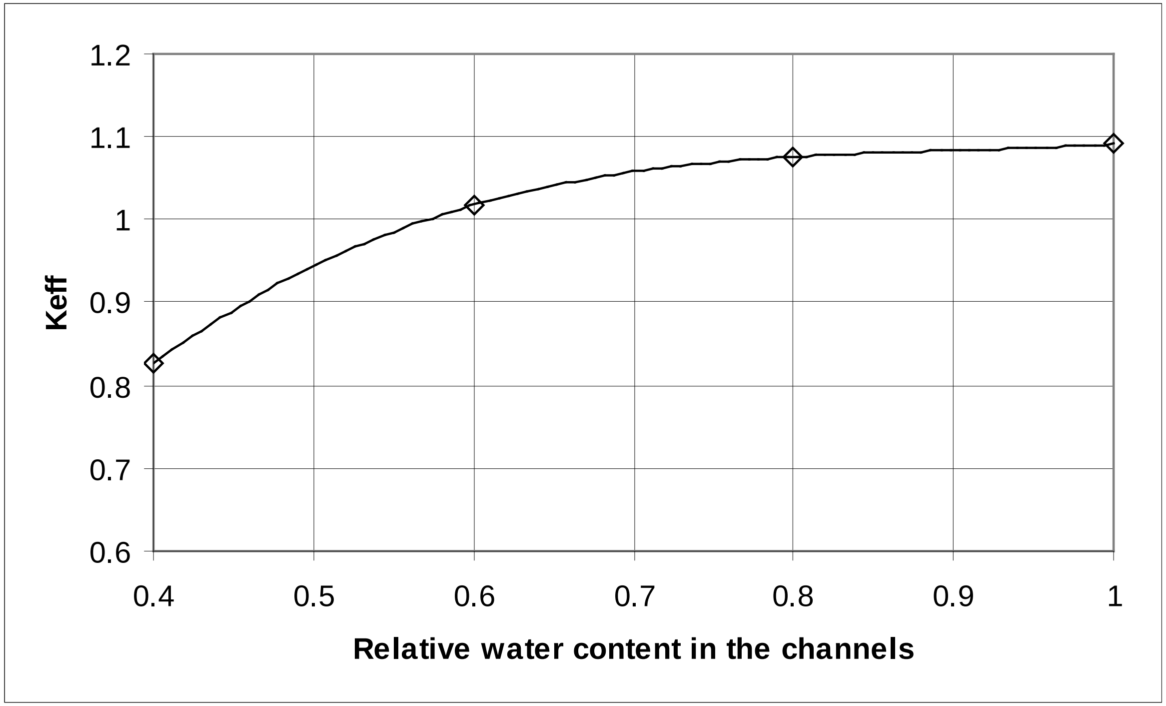




Reactivity increase up to 0.003 Δk

Demolition of fuel assemblies

The fuel assembly materials are mixed homogenously with the water in the compartmens. PWR-results:



Uncertainties

- **Declared burnup**
- **Axial void- and temperature distribution**
- **Axial burnup distribution**
- **Control rods**
- **Horizontal burnup distribution**
- **Geometry changes due to irradiation**

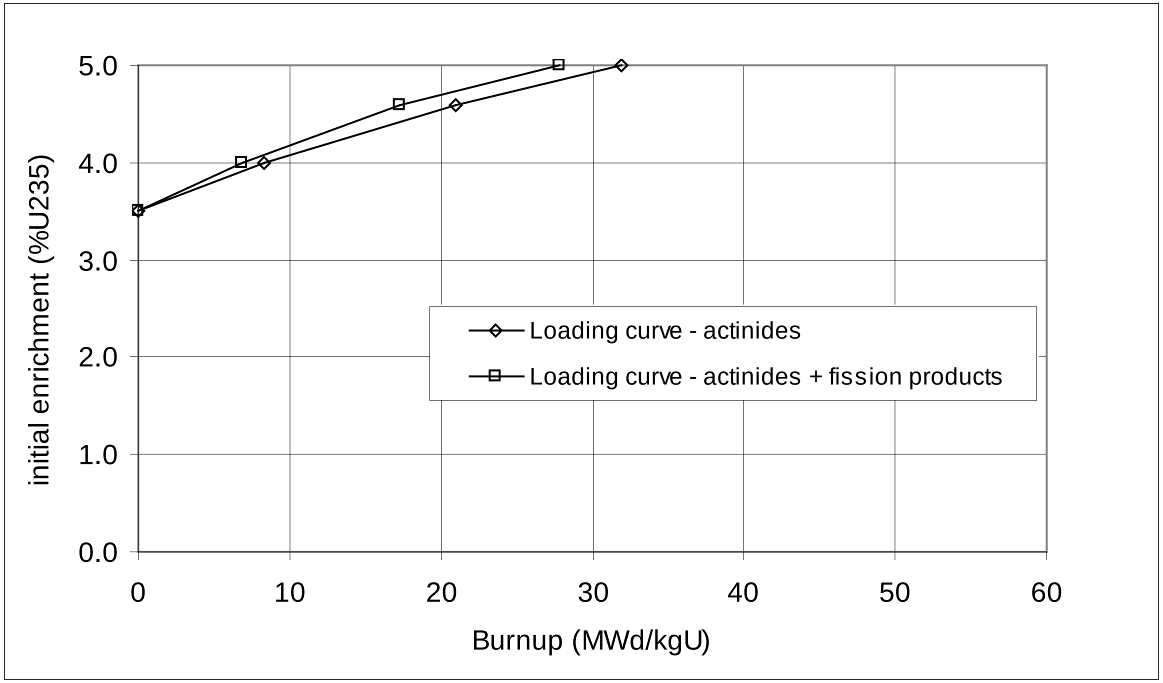
- **Calculational uncertainty**
- **Uncertainty in isotopic prediction**

- **Manufacturing tolerances in canister and fuel**

BU-requirement for BWR

Case	Actinides	Actinides+ fissions-products
Uncertainties in fuel data	0.0023	0.0023
Statistical uncertainty in KENO	0.0009	0.0009
Bias in benchmarking	0.0007	0.0007
Calcunational uncertainty	0.0093	0.0093
Uncertainty and bias in nuclide calculation	0.0156	0.0259
Uncertainty in burnup	0.0073	0.0080
End effect	0.0467	0.0531
Horizontal burnup distribution	0.0055	0.0065
Long term effect	0.0000	0.0000
Defects in the cansister	0.0030	0.0030
Change in geometry due to burnup	0.0031	0.0031
Sum	0.0945	0.1128
Keff in base case	1.0188	1.0188
Sum keff	1.1133	1.1316
Limit vaule	0.9500	0.9500
Need of BU-cred	0.1633	0.1816
Bu coefficient (dk/MWd/kgU)	0.0051	0.0065
Burnup requirement (MWd/kgU)	**32.0**	**27.8**

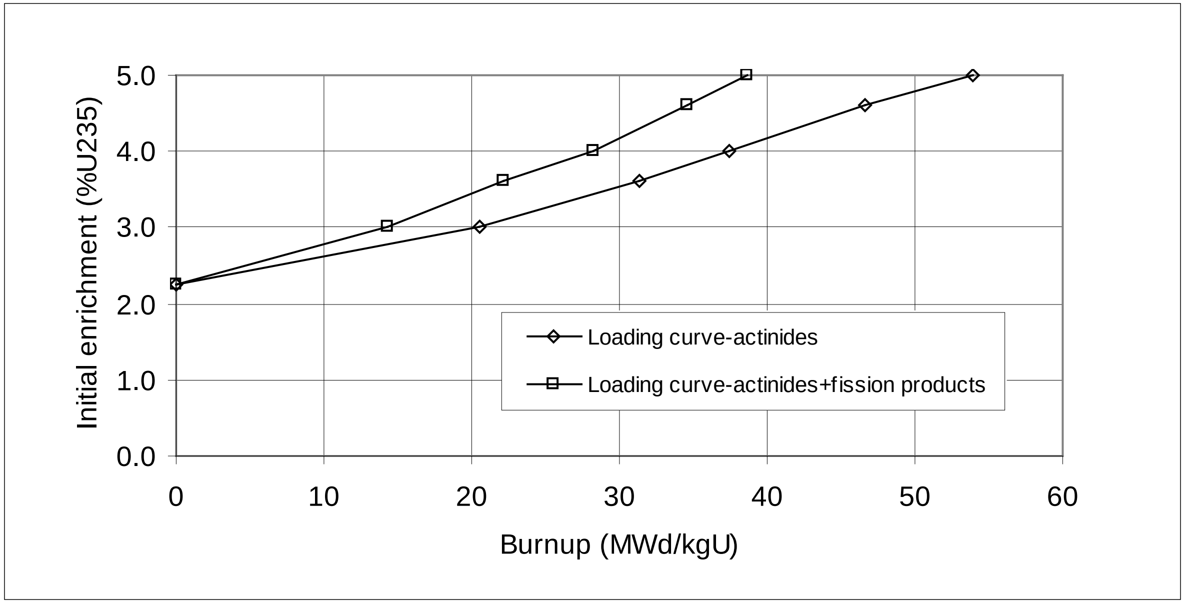
Loading curves for BWR in final storage canisters



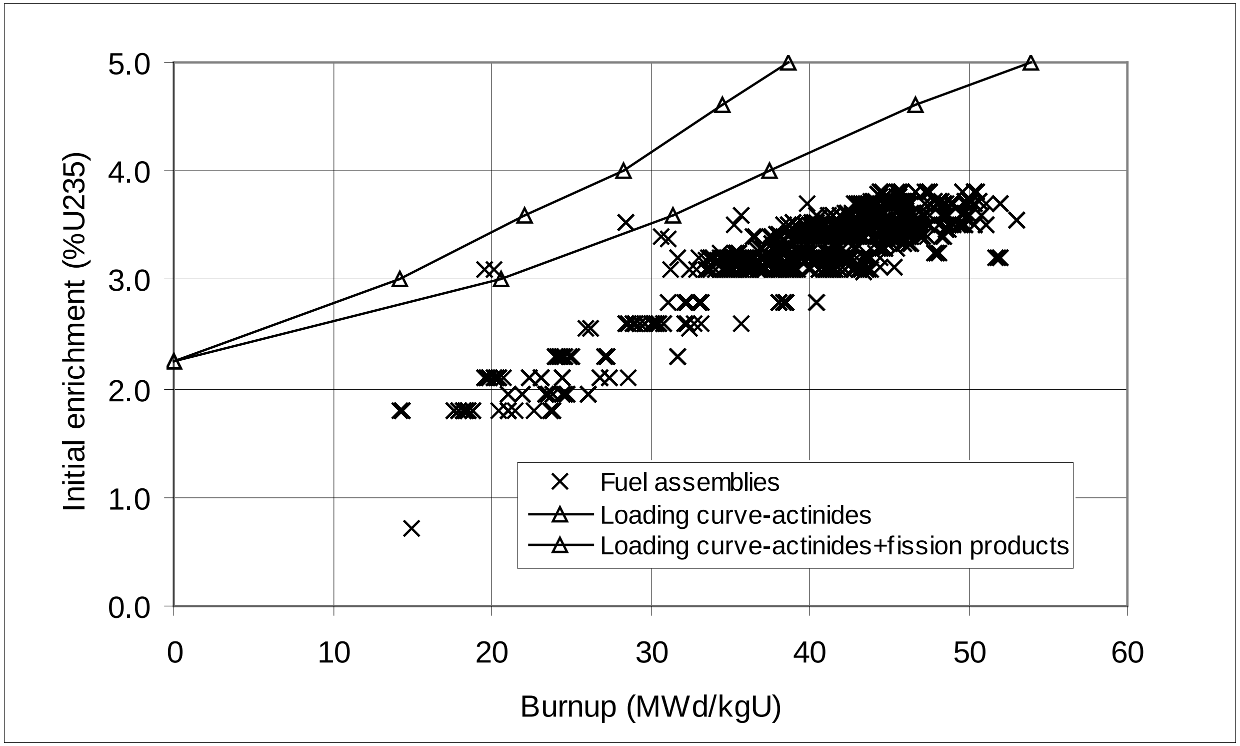
BU-requirement for PWR

Case	Actinides	Actinides+ fissions products
Uncertainties in fuel data	0.0031	0.0031
Statistical uncertainty in KENO	0.0009	0.0009
Bias in benchmarking	0.0007	0.0007
Calcunational uncertainty	0.0093	0.0093
Uncertainty and bias in nuclide calculation	0.0229	0.0277
Uncertainty in burnup	0.0095	0.0097
End effect	0.0047	0.0000
Horizontal burnup distribution	0.0093	0.0091
Long term effect	0.0000	0.0000
Defects in the canister	0.0030	0.0030
Change in geometry due to burnup	0.0031	0.0031
Sum	0.0665	0.0666
Keff in base case	1.1082	1.1082
Sum keff	1.1747	1.1748
Limit vaule	0.9500	0.9500
Need of BU-cred	0.2247	0.2248
Bu coefficient (dk/MWd/kgU)	0.0042	0.0058
Burnup requirement (MWd/kgU)	**53.9**	**38.7**

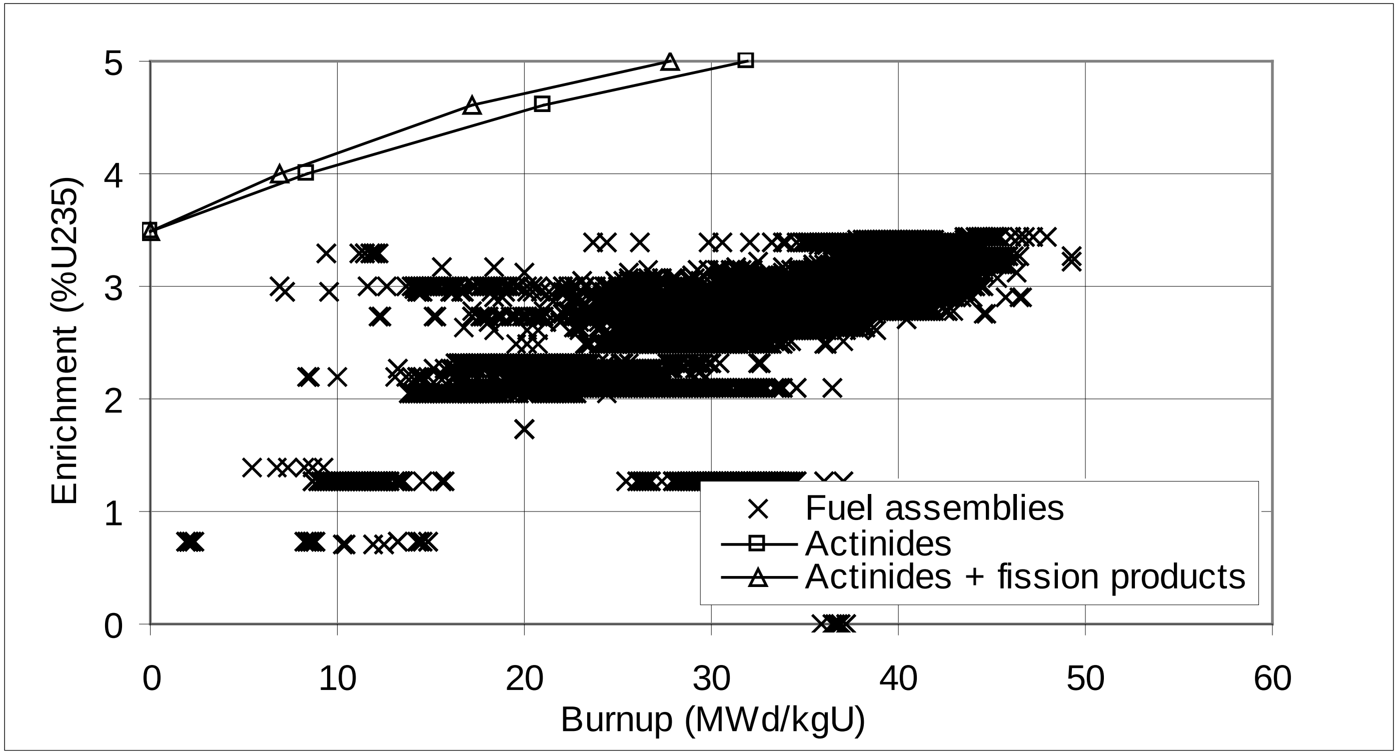
Loading curves for PWR in final storage canisters



Loading curves for PWR compared to the Clab inventory



Loading curves for BWR compared to the Clab inventory

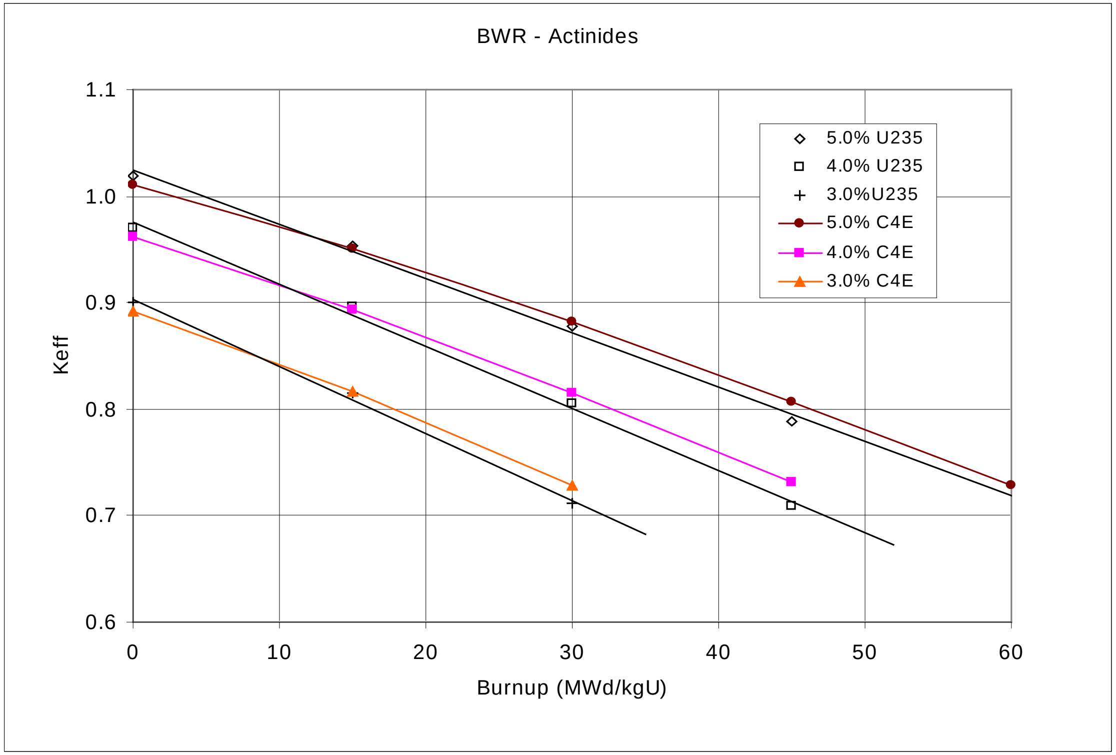


Conclusions for BUC in final storage canisters

- **All BWR-assemblies in the programme could be stored in canisters for final storage using burnup credit for actinides only. If additional actinides and fission products are included more margin is obtained.**

- **All PWR-assemblies stored in CLAB at the end of 2007 except for 20 could be accepted for storage in canisters for final storage using burnup credit for actinides only. The same is also valid for future fuel. If additional actinides and fission products are included all assemblies meet the criteria.**

Comparison SAS2/KENOVa CASMO



Questions

- Validation of codes for BWR
- How to find a limiting axial burnup distibution