Evaluation and Parameter Analysis of Burn up Calculations for the Assessment of Radioactive Waste

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The purpose of this work is to define and verify the range of validity and limitations of correlations used for nuclear waste characterization and to scrutinize the dependencies and propagation of uncertainties that affect the waste inventory declarations and their independent verification. This is accomplished by numerical assessment and simulation of waste production using well accepted codes SCALE 6.0 and 6.1 to simulate the cooling time and burn up of a spent fuel element. The simulations are benchmarked against spent fuel from the pressurized water reactor Obrigheim in Germany for which sufficiently precise experimental reference data are available.

Table I. Calculation vector from SFCOMPO data base [1]

Variable	Unit
1. Cs-134/Cs-137 [1]	Bq/Bq
2. Cs-137/U-238 [1]	mol/mol
3. Eu-154/Cs-137 [1]	Bq/Bq
4. Kr-83/Kr-86 [2]	mol/mol
5. Kr-84/Kr-86 [2]	mol/mol
6. Kr-85/Kr-86 [2]	mol/mol
7. Nd-148/U-238	mol/mol
8. Pu-238/Total Pu	kg/kg
9. Pu-239/Total Pu	kg/kg
10. Pu-239/U-238	mol/mol
11. Pu-240/Pu-239	mol/mol
12. Pu-240/Total Pu	kg/kg
13. Pu-241/Pu-239	mol/mol
14. Pu-241/Total Pu	kg/kg
15. Pu-242/Pu-239	mol/mol
16. Pu-242/Total Pu	kg/kg
17. Total Pu/Total U	mol/mol
18. Total Pu/Total U	kg/kg
19. U-235/Total U	kg/kg
20. (U-235/Total U)/(U-235/Total U init)	kg/kg
21. U-235/U-238	mol/mol
22. U-236/Total U	kg/kg
23. U-236/U-238	mol/mol
24. U-238/Total U	kg/kg
25. Xe-131/Xe-134 [2]	mol/mol
26. Xe-132/Xe-134 [2]	mol/mol
27. Xe-136/Xe-134 [2]	mol/mol
28. Burn up (by Cs-137 Destructive method) [1]	GWd/MTU
29. Burn up (by Cs-137 Non-destructive method) [1]	GWd/MTU
30. Burn up (by Nd-148 method)	GWd/MTU
31. Burn up (by Theoretical)	GWd/MTU
32. Am-241 [1]	kg
33. Cm-242	kg
34. Cm-244	kg
35. Cs-134 [1]	kg
36. Cs-137 [1]	kg
37. Eu-154 [1]	kg
38. Pu-238	kg
39. Pu-239	kg
40. Pu-240	kg
41. Pu-241	kg
42. Pu-242	kg
43. Total Pu	kg
44. Total Pu, U	kg
45. Total U	kg
46. U-235	kg
47. U-235 Depletion	kg
48. U-236 Build-up	kg
49. U-238	kg
50. U-235 Depletion	kg

1 Only from "Joint Research Center" (Ispra)
2 Only from Karlsruhe Institute of Technology (Karlsruhe)

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Figure I. Deviation between measured and simulated (left frame for arp model and right frame for newt model) data for the fuel element (BE 124) of the NPP Obrigheim. Measurement position RodG7p3 [1], BU = 31.5 GWd/MTU

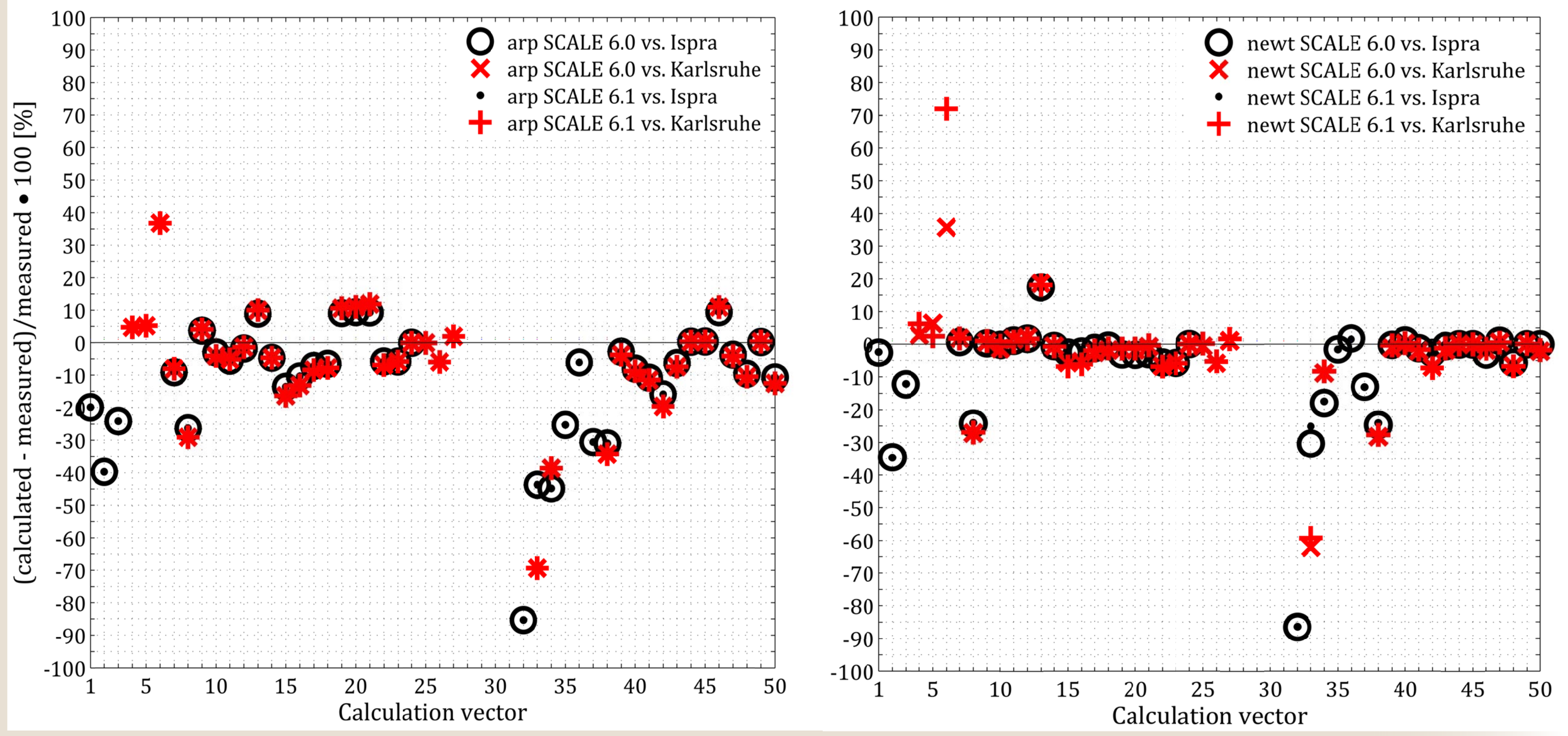
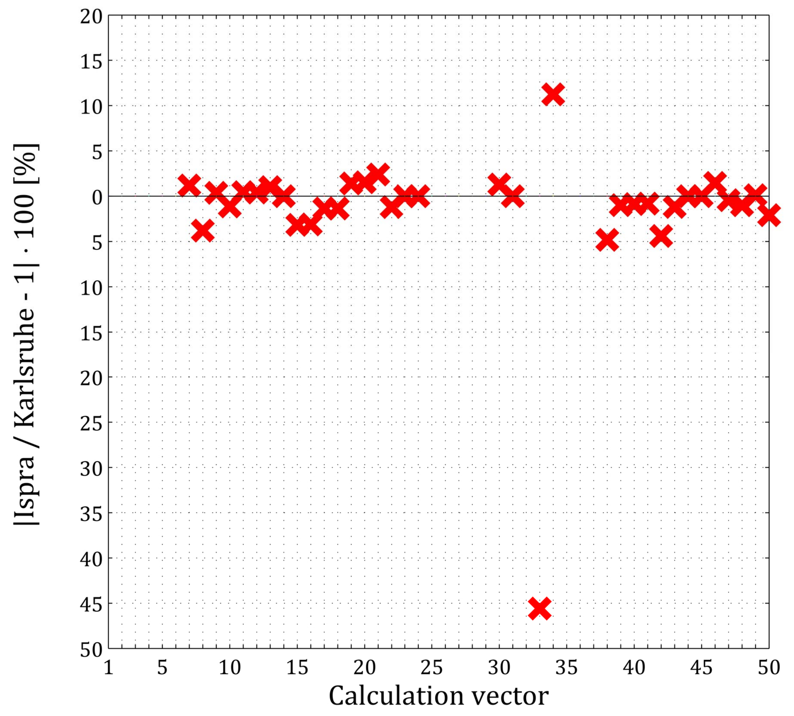


Table II. Summary of parameters for the NPP Obrigheim reactor and fuel element BE 124 [1]

Type of reactor	PWR
Considered operating time	1970 – 1974
Type of fuel element	Siemens 14 × 14
Fuel	UO_2
Initial enrichment of U-235	3.00%
Medium burn up	29 GWd/MTU
Fuel density	10.408 g/cm^3
Moderator density (H_2O)	0.7283 g/cm^3
Fuel tempeature	900 K
Moderator tempeature	570 K

Figure II. Relative deviation of two measurement sets for a fuel element (BE 124) from the NPP Obrigheim in Germany. Measurement position RodG7p3 [1], BU = 31.5 GWd/MTU



References:
[1] http://www.oecd-nea.org/sfcompo/Ver.2/Eng/Obrigheim/index.html, Online 2013

VARIATIONAL ANALYSIS OF THE CORRELATION BANDWIDTH

SECONDARY REACTOR PARAMETERS

- Fuel properties: initial enrichment, density, temperature
- Moderator properties: density, temperature

KEY NUCLIDE is such a radionuclide that can be detected easily through its characteristic gamma rays by means of non-destructive methodology (Cs-134, Cs-137, Eu-154).

MODEL FOR VARIATIONAL ANALYSIS

- Fuel element: NPP Obrigheim BE 124
- Burn up: 60 GWd/MTU
- Initial enrichment: 1.5%, 3%, 4.5%
- Fuel temperature: 900 K, 1800 K
- Moderator temperature: 556 K, 586 K
- Fuel density: 90%, 100% respective of the physical fuel density (Table II)
- Moderator density: 90%, 110% respective of the physical moderator density (Table II)

Figure III. Build-up of Eu-154 as a function of burn up (left frame) and corresponding bandwidth (right frame)

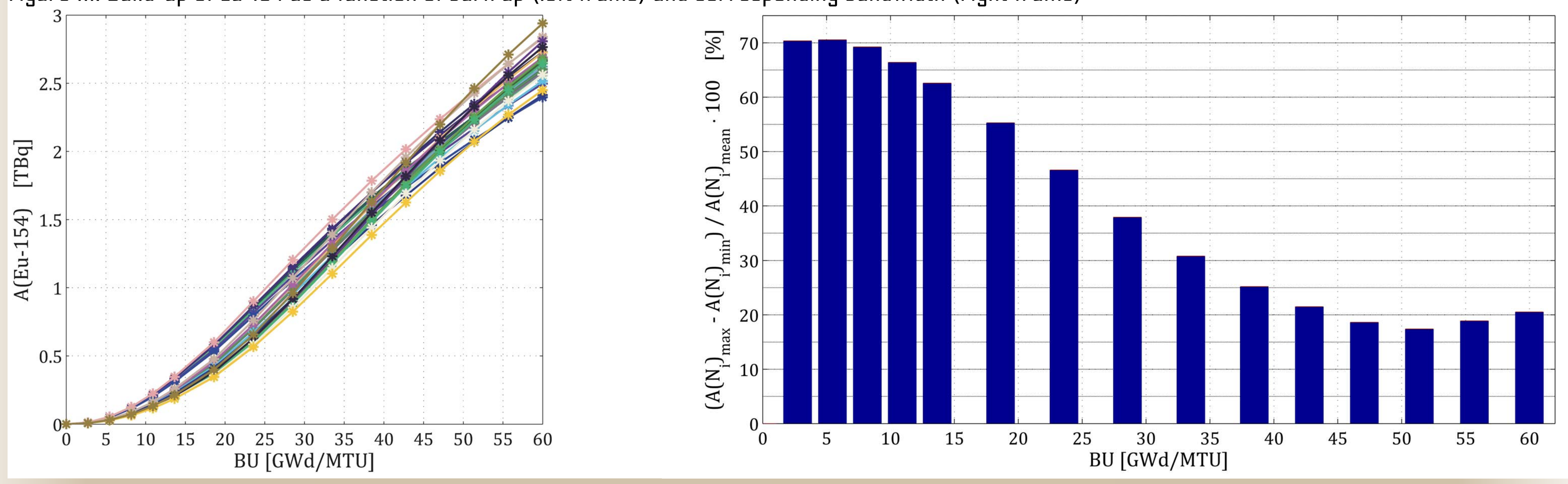


Figure IV. Build-up of Cs-134 as a function of burn up (left frame) and corresponding bandwidth (right frame)

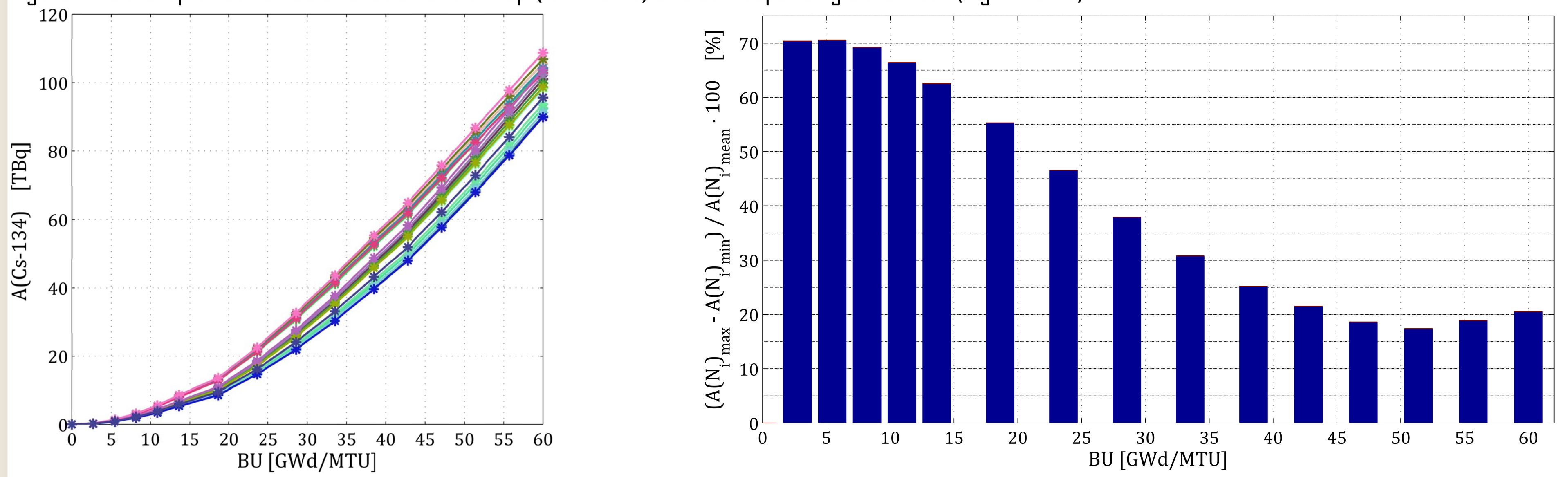
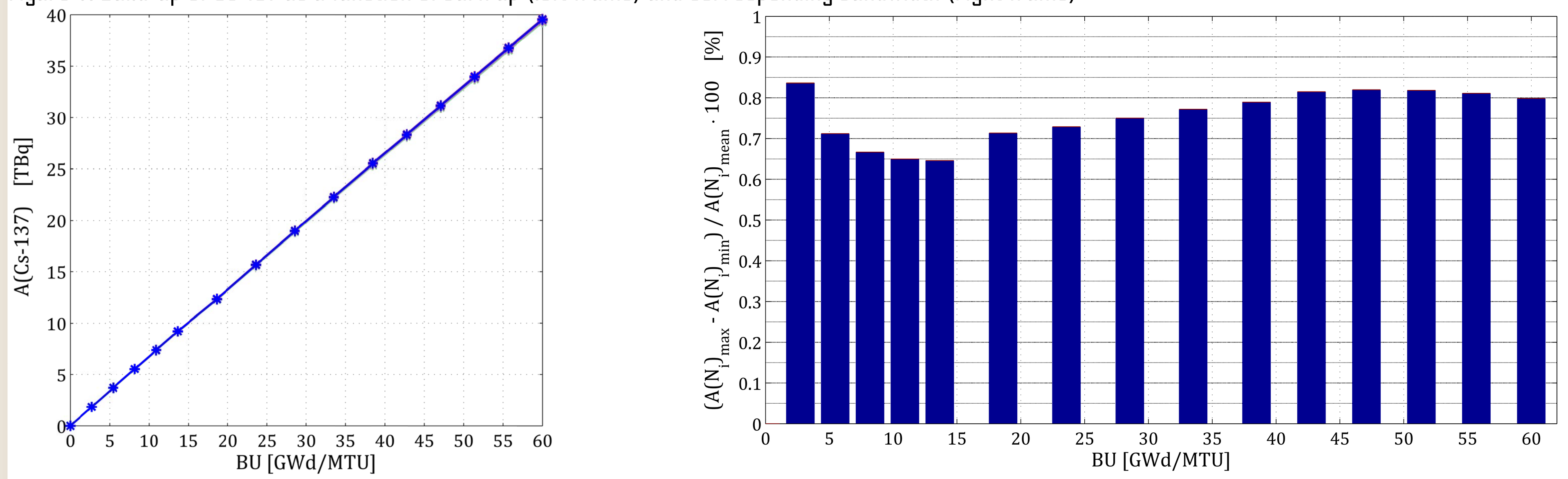


Figure V. Build-up of Cs-137 as a function of burn up (left frame) and corresponding bandwidth (right frame)



BURN UP CORRELATION Eu-154/Cs-137

Figure VI. Build-up of Eu-154 (left frame) and Cs-137 (right frame) as a function of burn up. Calculations are performed with SCALE 6.1 using newt model for burn ups < 60 GWd/MTU

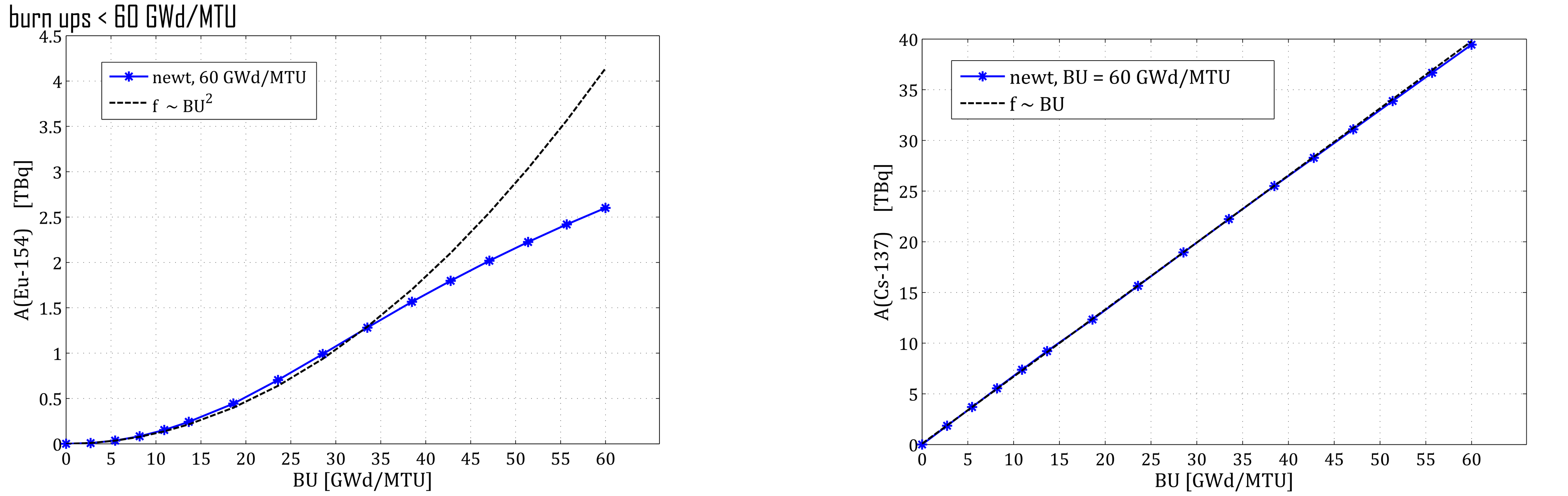
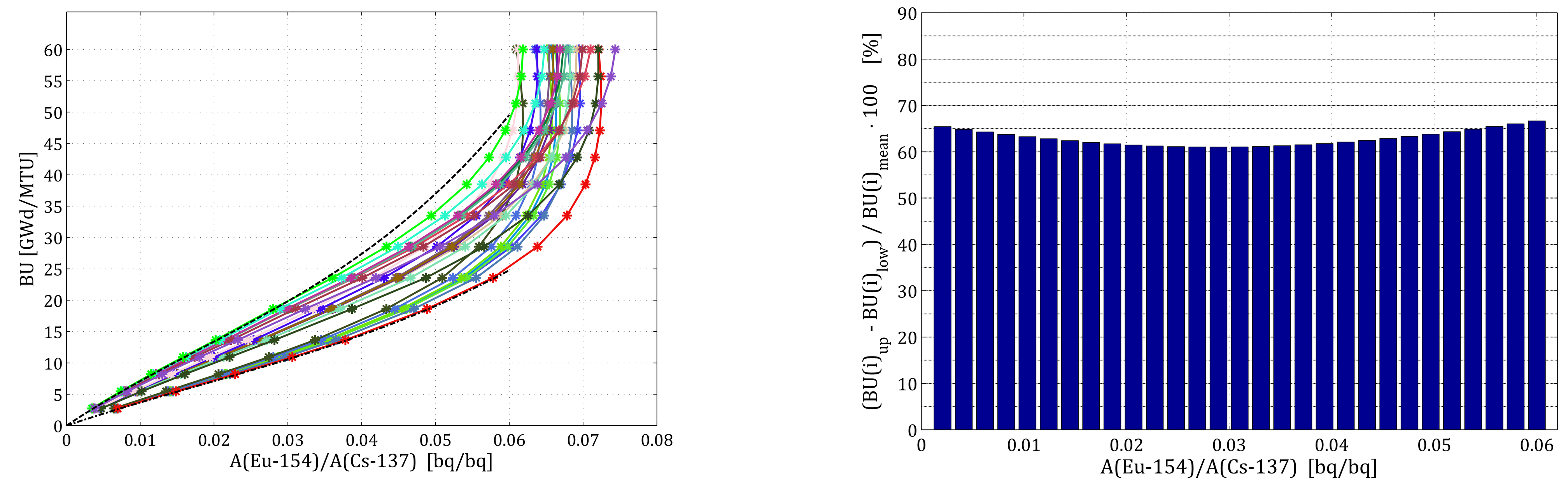


Figure VII. Burn up as a function of the ratio Eu-154/Cs-137 (left frame) and the corresponding bandwidth (right frame). Calculations are performed with SCALE 6.1 using newt model for burn ups up to 60 GWd/MTU



COOLINGTIME CORRELATION Eu-154/Cs-134

Figure VIII. Cooling time is as a function of the ratio Eu-154/Cs-134 (left frame) and the corresponding bandwidth (right frame). Calculations are performed with SCALE 6.1 using newt model for burn ups up to 60 GWd/MTU