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Title: Commonly Overlooked Material Attractiveness Issues

Author(s): Bathke, Charles G.

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Commonly Overlooked Material Attractiveness Issues

Charles G. Bathke

Los Alamos National Laboratory

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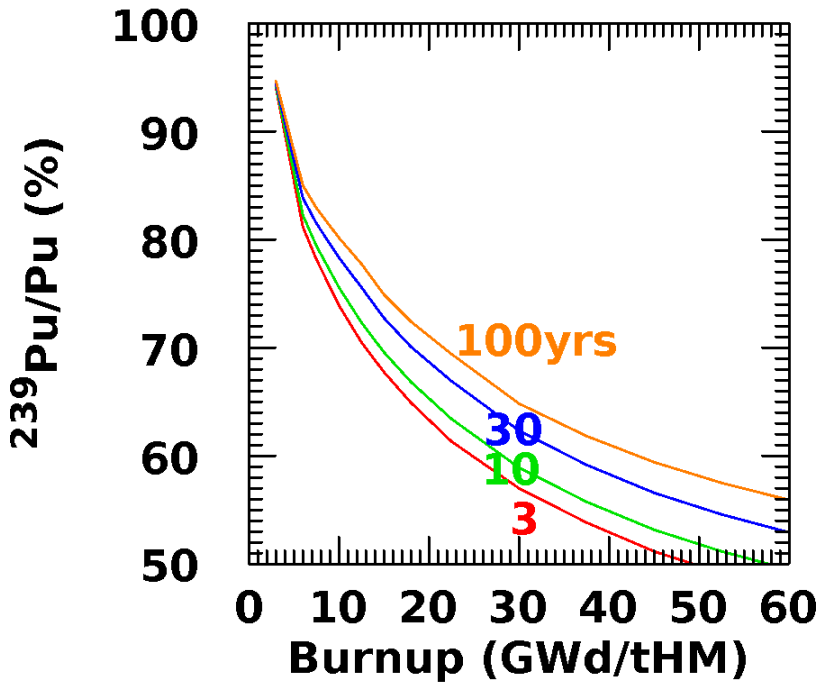
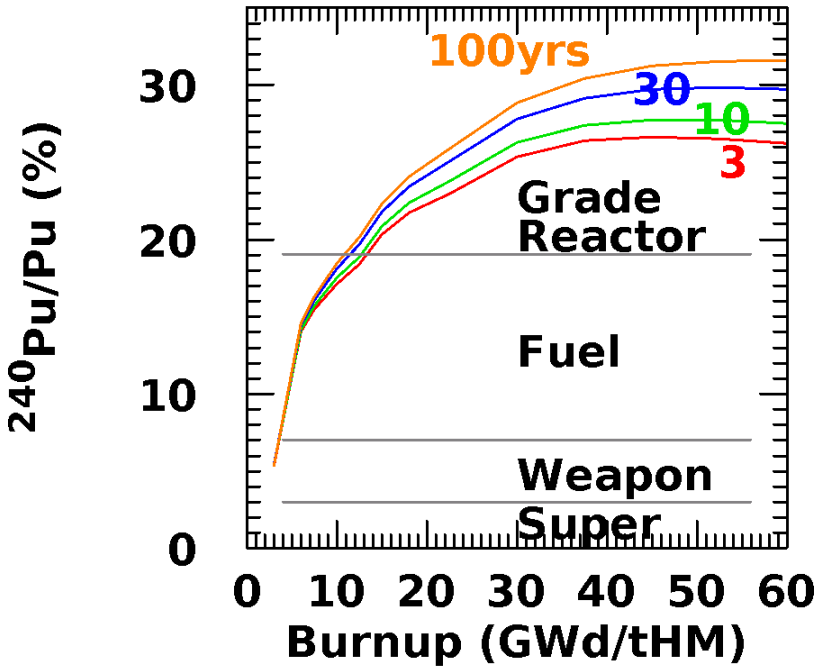
WG-Pu is typically considered the most attractive plutonium, but is it?

- All compositions are:
  - Generated with ORIGEN
  - For PWRs, but also applicable to BWRs
  - Generated with minimum enrichment to maintain $k_{eff} = 1$ over entire time an assembly is irradiated
- Conventional Wisdom (CW) says the most attractive Pu has the highest ^{239}Pu content and is produced in PWRs at low burnup
- The conclusion from the plot is that Pu becomes more attractive with age (i.e., spent fuel cooling time)



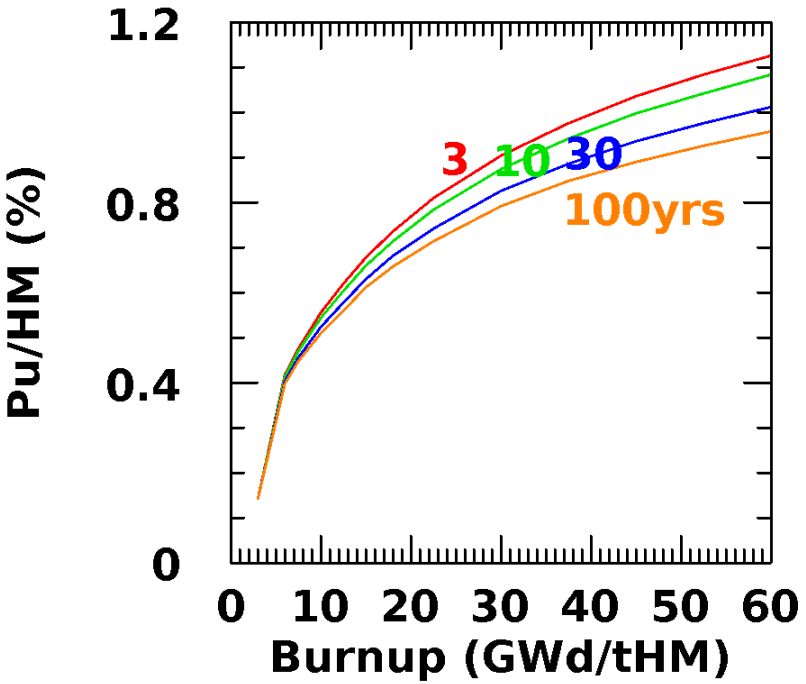
Historically, Pu was graded by its ^{240}Pu content, not its ^{239}Pu content

- WG-Pu was typically produced in thermal spectrum reactors
- However, the highest grade of Pu isn't produced in LWRs.
  - The highest grade is produced in fast spectrum reactors
  - The 4S, a fast small modular reactor (SMR), produces Pu with < 3% ^{240}Pu
- Are there any conditions under which RG-Pu would be considered preferable for diversion or theft?



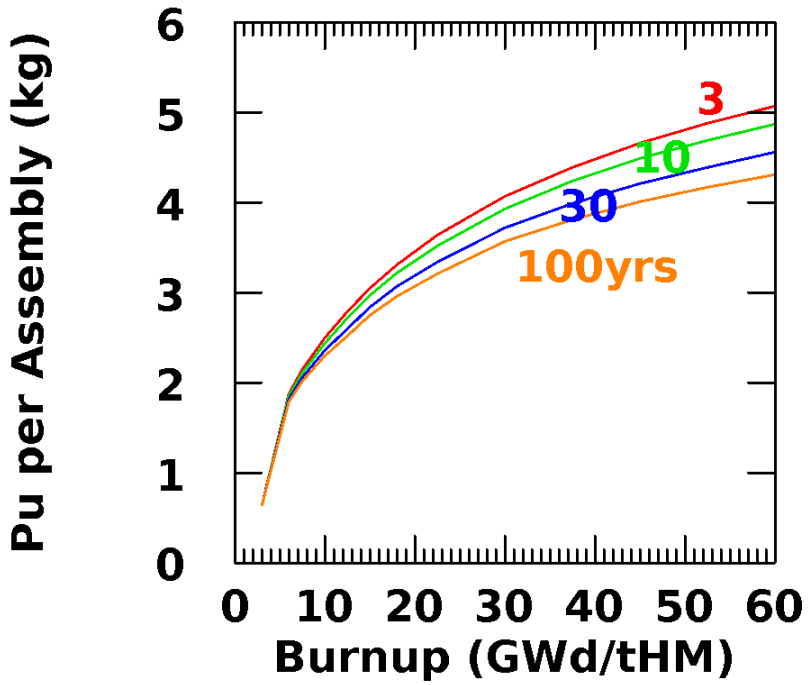
What is the Pu concentration in spent PWR fuel?

- CW says the Pu concentration relative to the initial heavy metal (HM) in spent PWR fuel is ~1%
- The actual Pu concentration in spent PWR fuel is very dependent on the burnup of the fuel and to a lesser extent on the spent fuel age at the time of processing

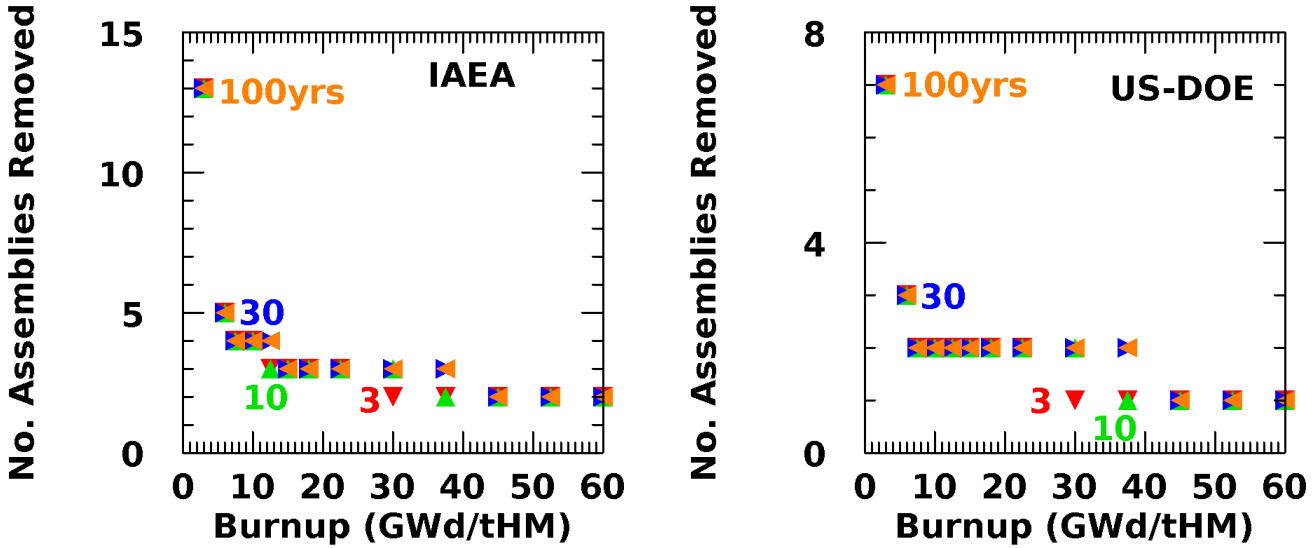


How much Pu is in spent PWR fuel?

- The amount of Pu in a spent PWR assembly varies from less than 1 kg to 5 kg, depending on burnup and cooling time

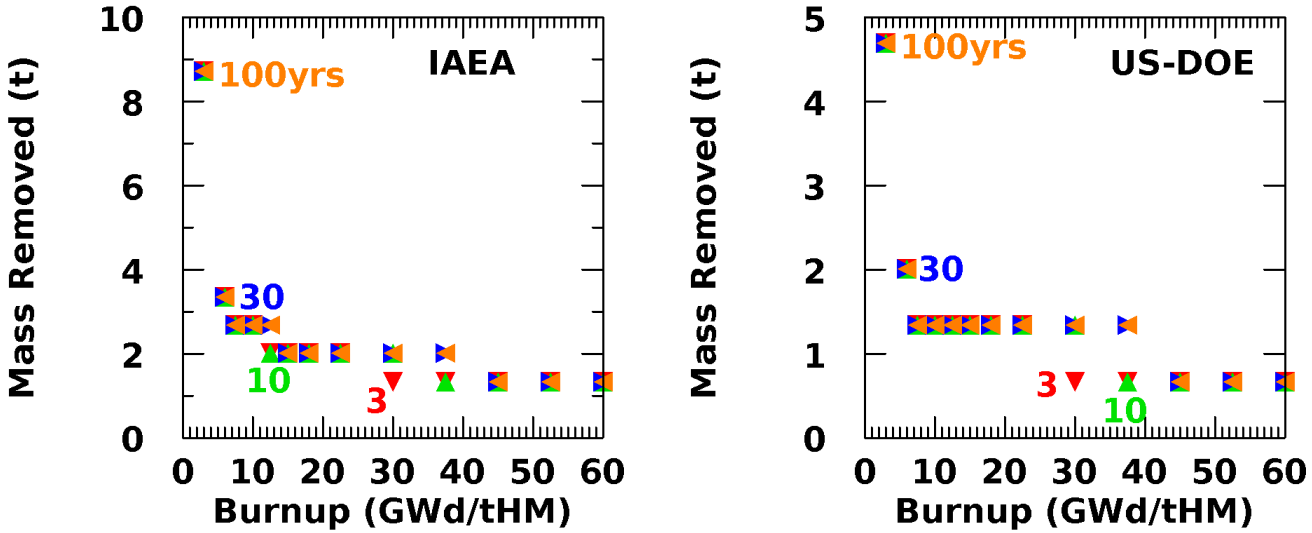


How many assemblies are required for a significant/sufficient quantity (SQ) of Pu?



- The IAEA and US DOE definitions of an SQ of Pu are 8 and 4 kg, respectively, because each organization makes different assumptions about their adversary
- It takes 13 and 7 assemblies to obtain an SQ of WG-Pu, but only 2 and 1 for an SQ of RG-Pu for the IAEA and US DOE SQ definitions, respectively

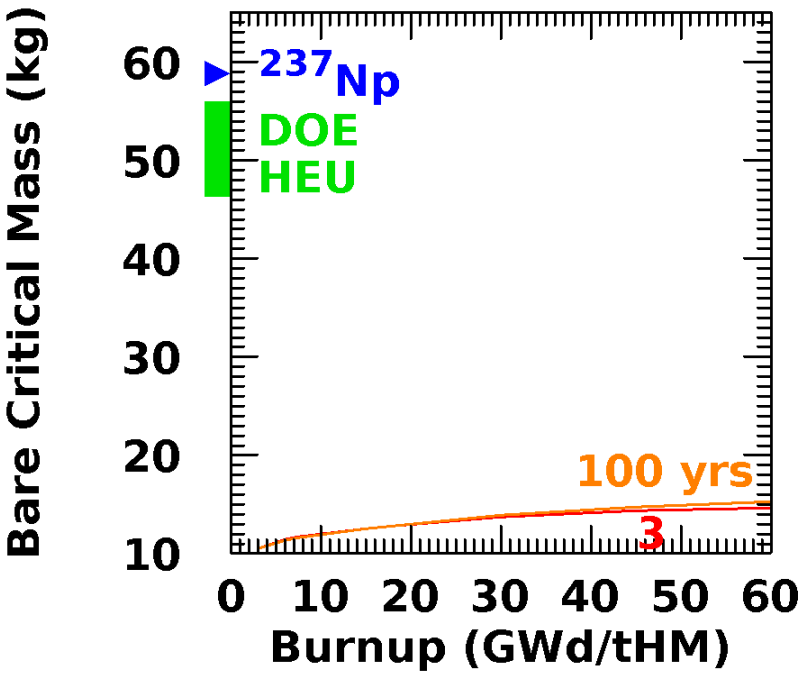
How much mass must be diverted/stolen (i.e., removed) for an SQ of Pu?



- It takes ~9 and ~5 metric tons to obtain an SQ of WG-Pu, but 1.3 and 0.7 tons for an SQ of RG-Pu for the IAEA and US DOE SQ definitions, respectively
- This large disparity between the acquisition mass for WG-Pu and RG-Pu will make RG-Pu far more attractive than WG-Pu according to the Nuclear Security Working Group (NSWG) Goal 9 grading algorithm

Is RG-Pu really that bad?

- The bare critical mass (BCM) of Pu produced in PWRs (i.e., RG-Pu) does not vary significantly with burnup or cooling time when compared to the BCM of other materials
  - The BCM of ^{237}Np is shown in blue in plot
  - The range of BCM for US DOE HEU (i.e., $^{235}U > 90\%$) is shown in green in plot
  - IAEA HEU (i.e., $^{235}U > 20\%$) would extend up to 800 kg



Summary

- SG-Pu, WG-Pu, FG-Pu, RG-Pu, HEU, and Np should not be ignored in safeguards or security discussions:
  - Nation states prefer SG-Pu and WG-Pu for missile delivery
  - Terrorists and some nation states will prefer FG-Pu and RG-Pu to minimize the mass that must be stolen/diverted and to minimize the risk of detection
  - Terrorists and some nation states will prefer HEU to eliminate the need for testing
  - A nation state with reprocessing capabilities might prefer ^{237}Np because the IAEA doesn't require it to be safeguarded
    - Terrorists might prefer ^{237}Np if the nation state does not provide adequate safeguards and security for it