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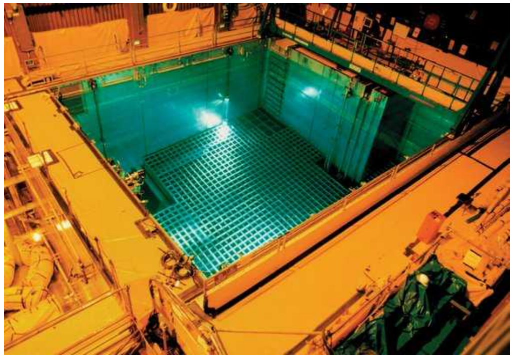

Cooling Times for Storage and Transportation of Spent Nuclear Fuel

Christine Stockman and Elena Kalinina

February 25, 2013

Summary

- Detailed information differs for different canister/cask designs, but general observations include these:
- Transfer from pool to cask within 5 years after reactor discharge is possible for smaller cask sizes, even for high burnup fuels
  - Individual assemblies could be cool enough, in principle, to load into dry storage at very early times, within days to weeks of reactor shut-down
- Increasing burnup results in increased pool storage time
  - Full loadings of high burnup fuels in very large casks may require decades of aging in pools
- Transportation may require additional aging, either in casks or pools
  - Decades of storage (in either pools or casks) may be required before transporting very large casks and higher burnup fuels

Two Approaches Give Similar Results

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Approach 1 (C. Stockman)

- Cooling times derived from cask NRC Certificates of Compliance
  - Information available for specific cask designs and loading configurations

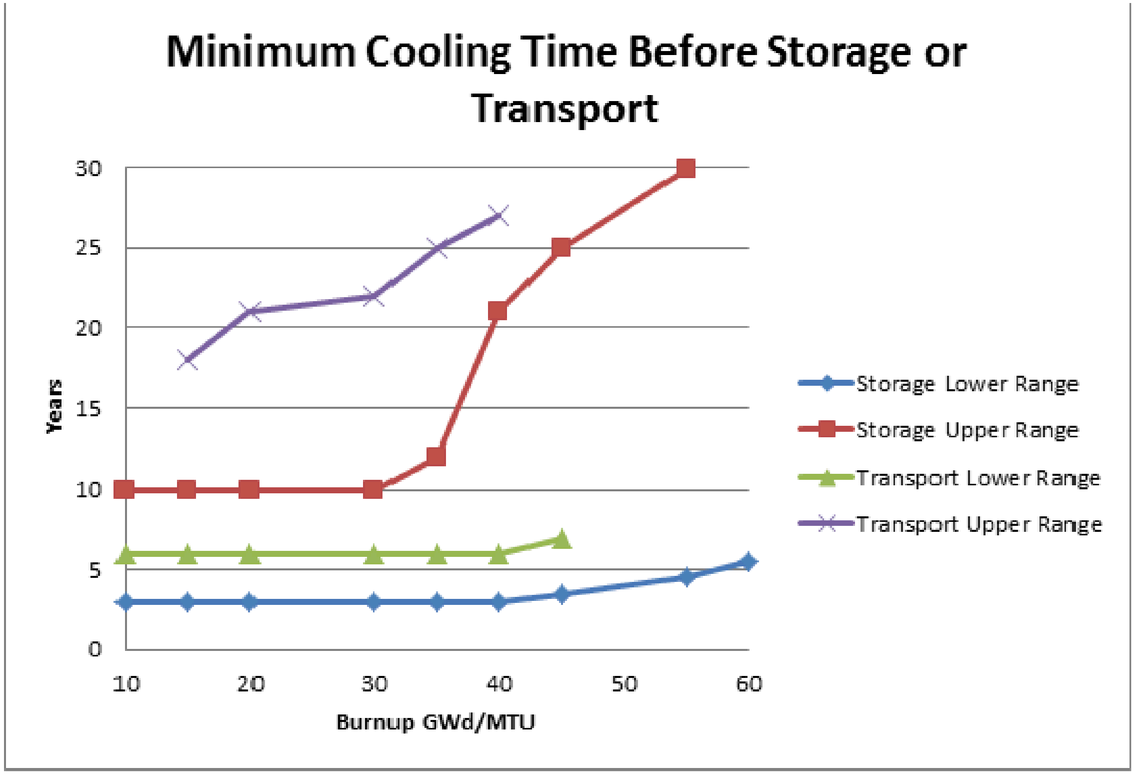
Approach 2 (E. Kalinina)

- Cooling times for storage only calculated from thermal decay data as a function of age, burnup, and enrichment, assuming a range of cask thermal power at the time of loading
  - Base case at 20kW/cask at time of loading is consistent with the upper bound of current practice, per NRC inspection reports of past cask loading operations
  - Cases run at higher cask thermal power values, possibly representative of future loading operations: 24 kW/cask is a typical PWR design limit, maximum current design loading limit is 40.8 kW/cask, for a 24 PWR configuration
  - Model uses generic cask designs loaded with representative numbers of BWR and PWR assemblies

Results are consistent between the two approaches:

- low assembly heat limits and/or high burnup = increased cooling time

Cooling Times Derived From Cask Certificates of Compliance



Upper and lower ranges represent specific cask designs and loading configurations

- Range of cooling time for any given value of burnup depends primarily on the design of casks and loading configuration
  - Some newer casks are designed to manage more heat
- Plot includes preferentially zoned loading (offsetting hotter assemblies with cooler ones in a single cask), where data are available
  - This extends the time range for a given burnup, particularly at the higher burnups.

Storage and Transportation Cooling Times Displayed Separately

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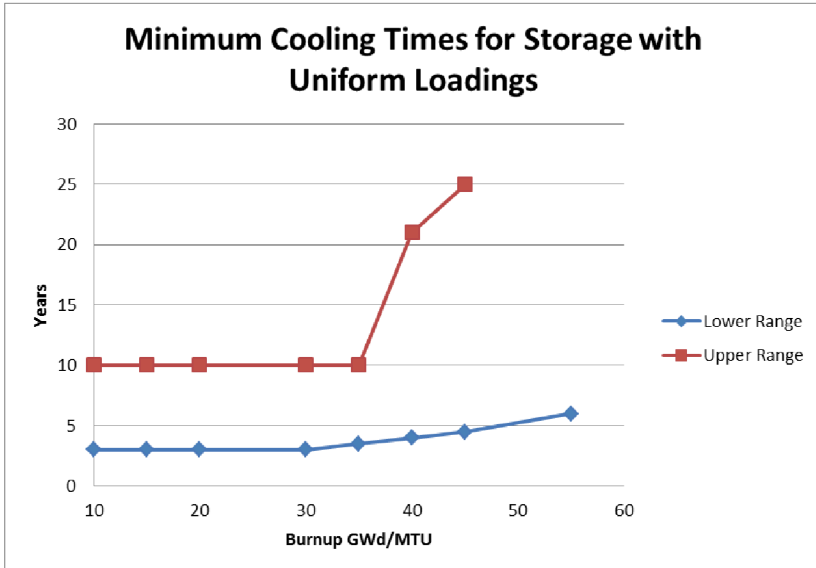
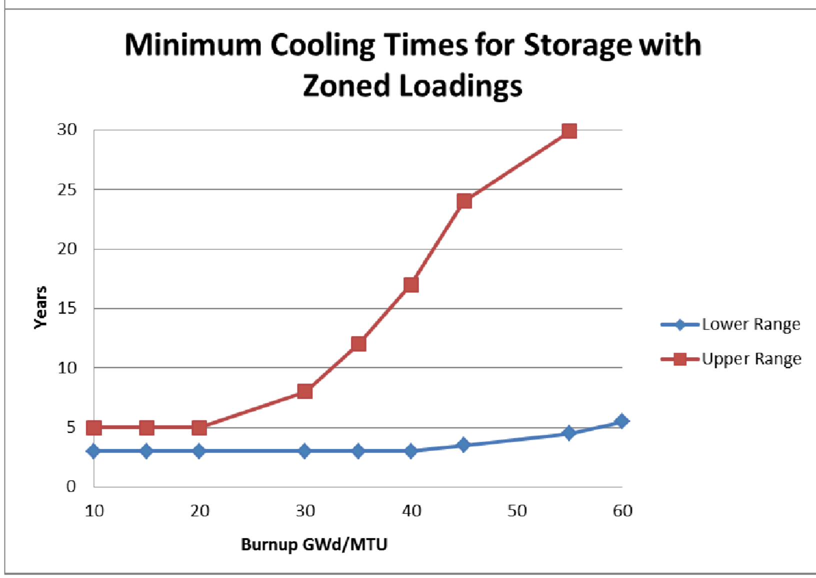
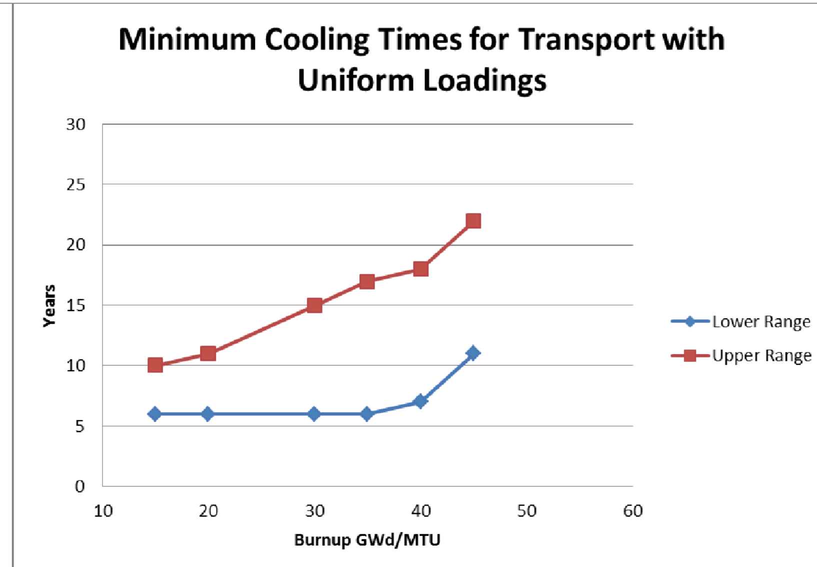
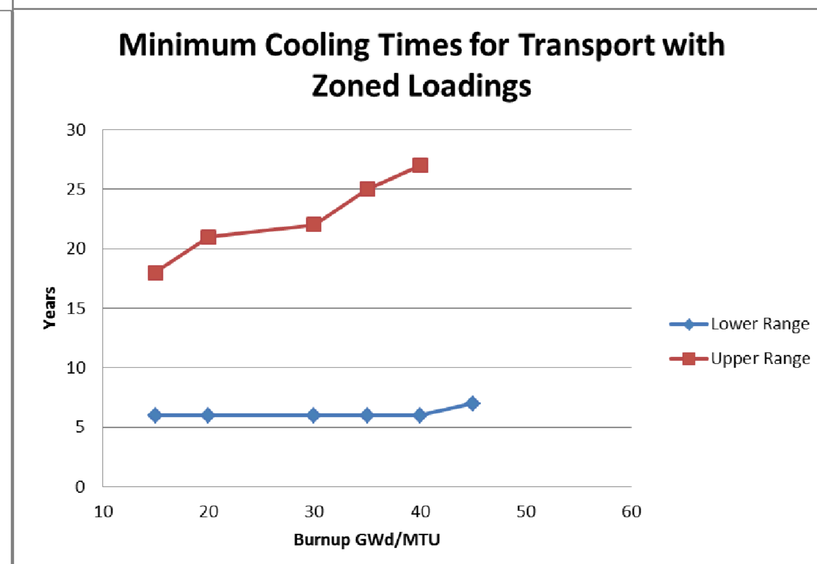
Storage



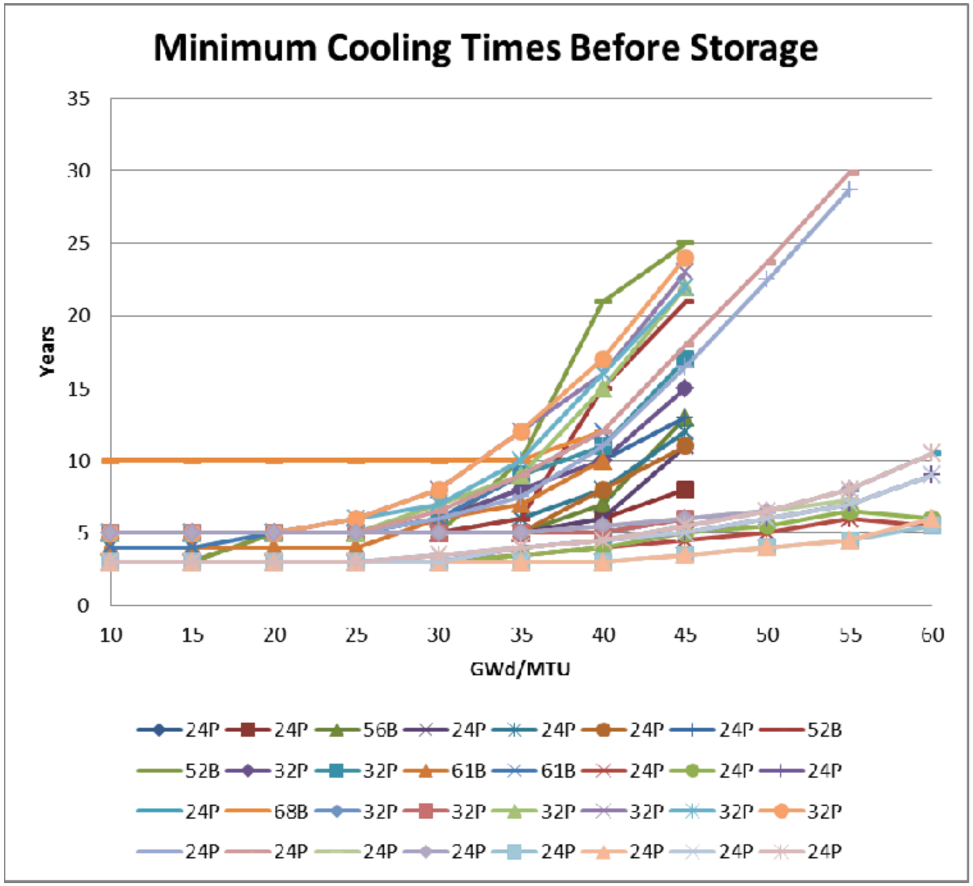


Transportation



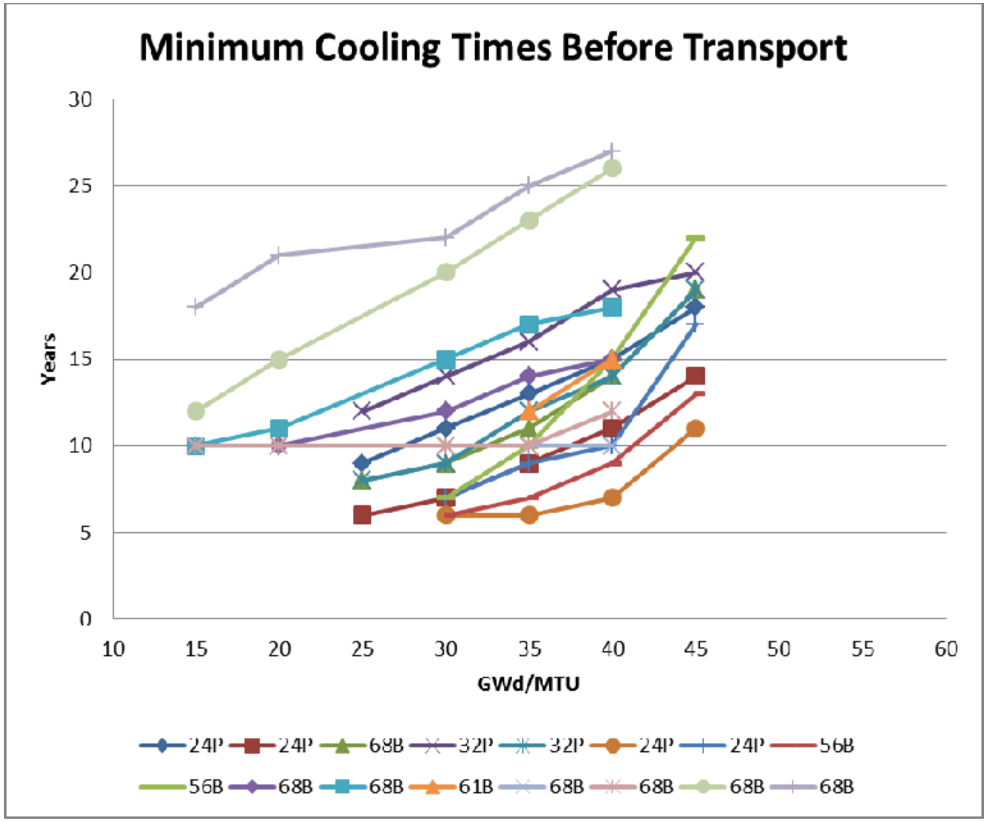


Cooling Time to **Storage** for Individual Cask Designs Allowing Preferentially Zoned Loading



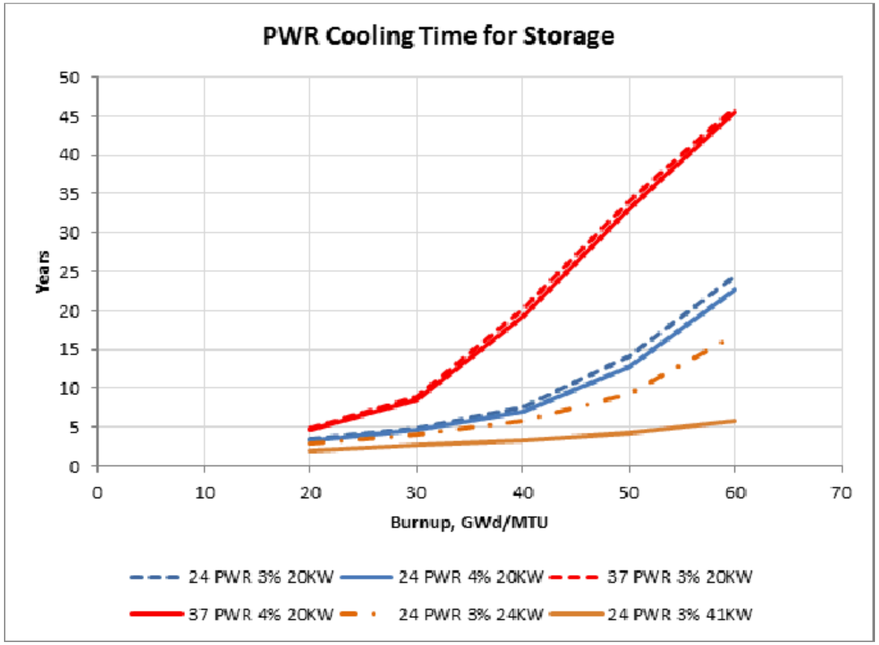
- Data are given for specific vendor cask designs
- The cask designs with the shortest cooling times before storage of 60 GWd/MTU fuel are all loadings of 24 PWR assemblies.
- Cooling times are not available for many designs with loadings of higher burnup fuels

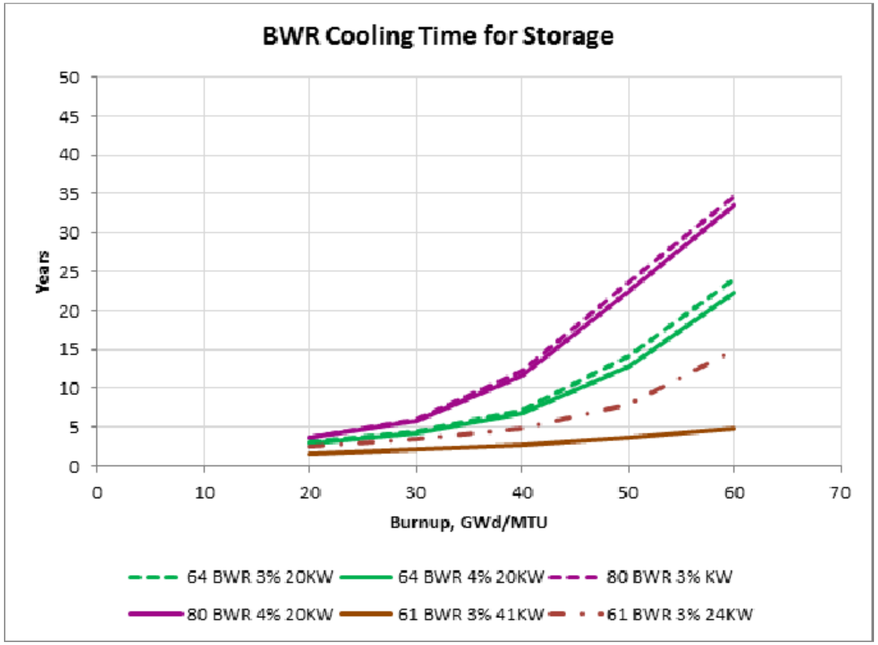
Cooling Time to **Transport** for Individual Cask Designs Allowing Preferentially Zoned Loading



- Data are given for specific vendor cask designs
- The cask designs with the longest cooling times before transport of 40 GWd/MTU fuel are all loadings of 68 BWR assemblies.
- Cooling times are not given for burnups greater than 45 GWd/MTU

Cooling Times Derived from Thermal Power Decay Data and Assumed Values for Peak Cask Thermal Output at Time of Loading



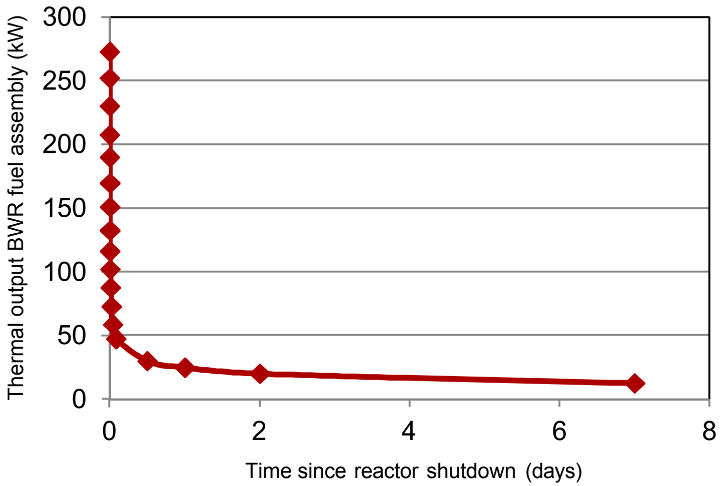


Base case of 20 kW limit per cask at the time of loading is consistent with the upper limit reported in NRC inspection reports of past loading operations.

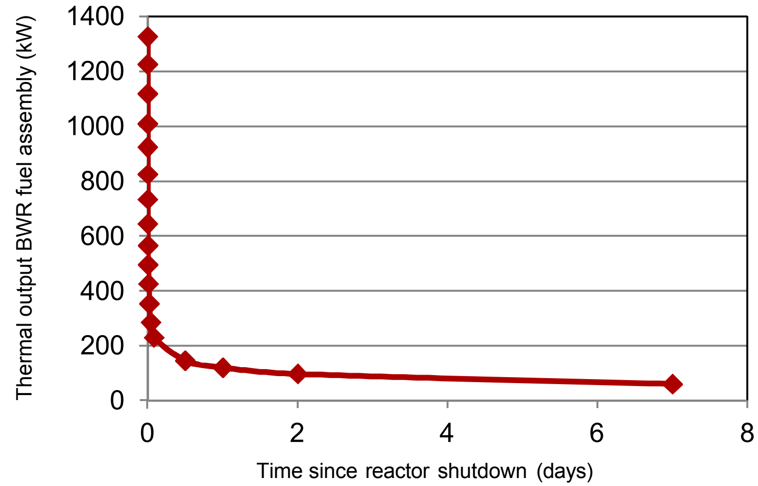
Higher limits represent potential future loadings based on current cask design limits; e.g. 24 kW/cask is a typical PWR design limit, and the maximum current design loading limit is 40.8 kW/cask, for a 24 PWR configuration.

Early-Time Cooling

MELCOR model output for average **BWR** high-burnup fuel assembly from Peach Bottom NPP, 59 GWd/MTU



MELCOR model output for average **PWR** high-burnup fuel assembly from Surry NPP, 59 GWd/MTU

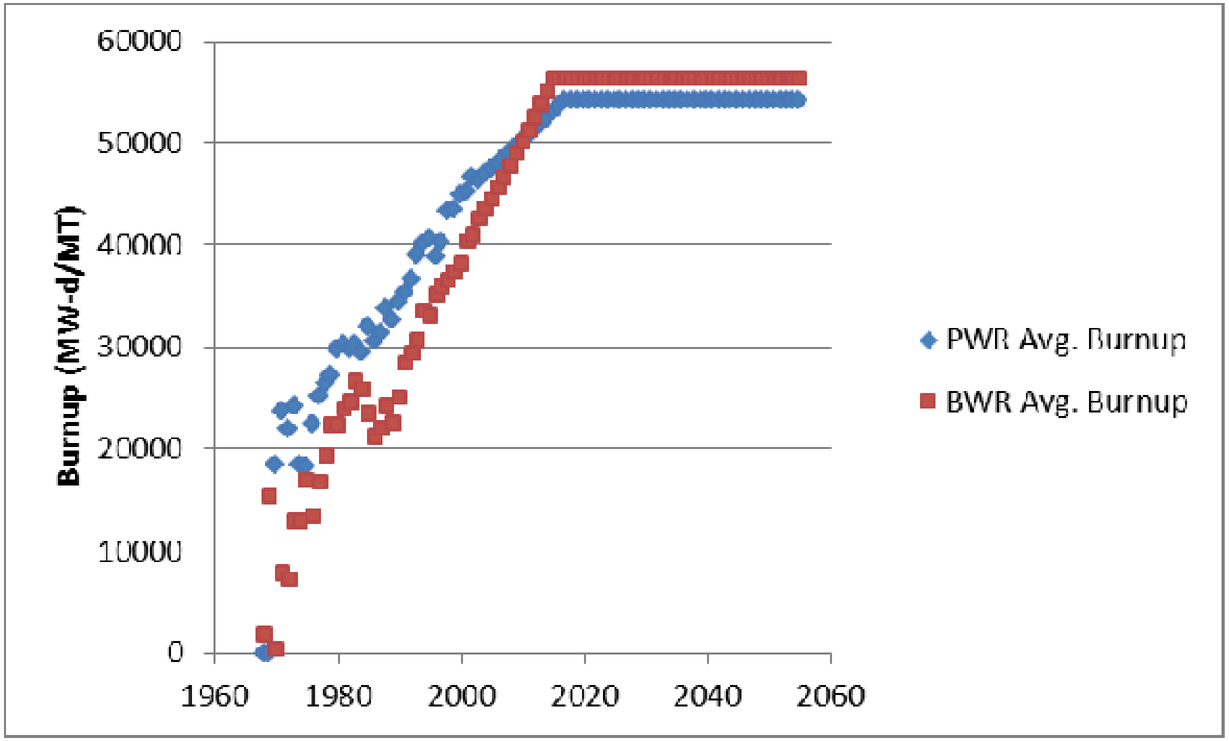


Earliest movement of fuel into dry storage will likely depend on multiple operational constraints other than thermal output, e.g.,

- Equipment availability
- Operator availability
- Handling rate
- Cask availability
- NRC approval

MELCOR data from D. Kalinich, plotted by P. Swift

Average Burnup of Past and Projected Discharges from US Commercial Nuclear Power Plants



Plotted by E. Hardin from Carter et al. 2012, Fuel Cycle Potential Waste Inventory for Disposition, FCR&D-USED-2010-000031 Rev 5, Appendix B.

Plot assumes license extensions for all existing nuclear power plants and no new nuclear power plant construction