SCALE Reactor Physics Applications to Fuels R&D: Increasing LWR Fuel Enrichment above 5%

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Acknowledgements

- This presentation draws from J. Burns, R. Hernandez, K. Terrani, A. Nelson, N. Brown, "Reactor and fuel cycle performance of light water reactor fuel with ^{235}U enrichments above 5%," *Annals of Nuclear Energy* **142** (2020) 107423.
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Context: Recent scientific advances in nuclear fuel materials has spurred interest in LWR fuel enrichments above 5%.

- Accident-tolerant fuel technology can enable an expanded operational envelope for LWRs
  - Improved safety margins
  - Higher fuel burnup
- Such benefits may be most fully realized with fuel enrichments above 5%
- **What are the reactor physics and fuel cycle implications of deploying LWR fuel with enrichments beyond 5%?**

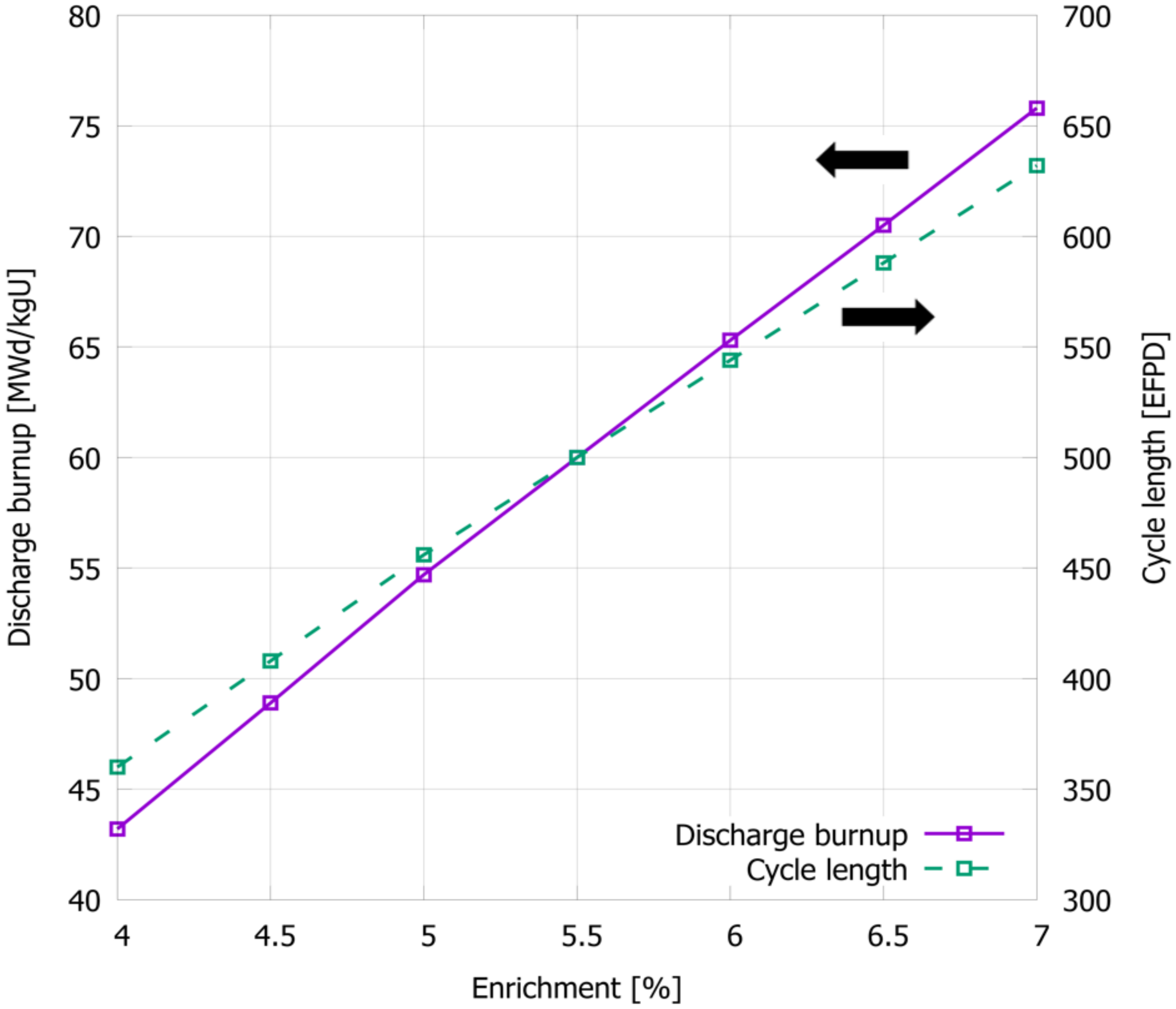
Simple SCALE models can yield a wealth of information about potential LWR performance with increased fuel enrichment.

- A 2D fuel pin cell is modeled for this study
  - Computational rigor is balanced to assess detailed fuel performance indicators – pin radial burnup profiles, Pu breeding, fission gas accumulation, …
  - Analytical models are used to estimate core performance and fuel cycle indicators based on pin cell results – discharge burnup, natural U metal input, spent fuel activity and decay heat, …

Methodology: TRITON is used to assess depletion of UO_2/Zirc-4 pins for enrichments of 4-7%

- Westinghouse 17x17 PWR assembly geometry is assumed
- Fine geometric resolution: 20 radial fuel divisions
- Branch cases are applied to assess reactivity coefficients (fuel temperature, moderator temperature, soluble boron)
- ORIGEN is applied separately after TRITON depletion to assess long-term spent fuel activity and decay heat

Results: Achievable discharge burnup increases by ~11 MWd/kgU/%



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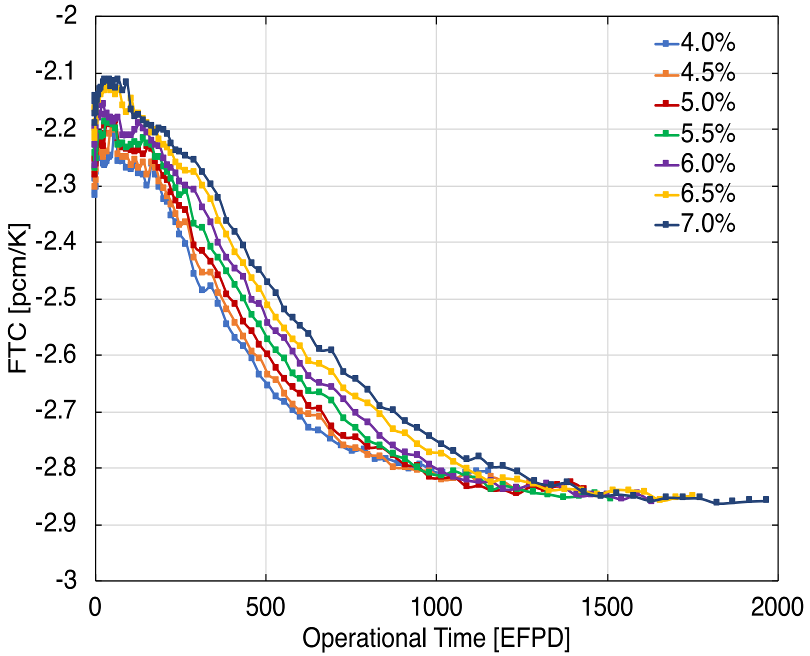
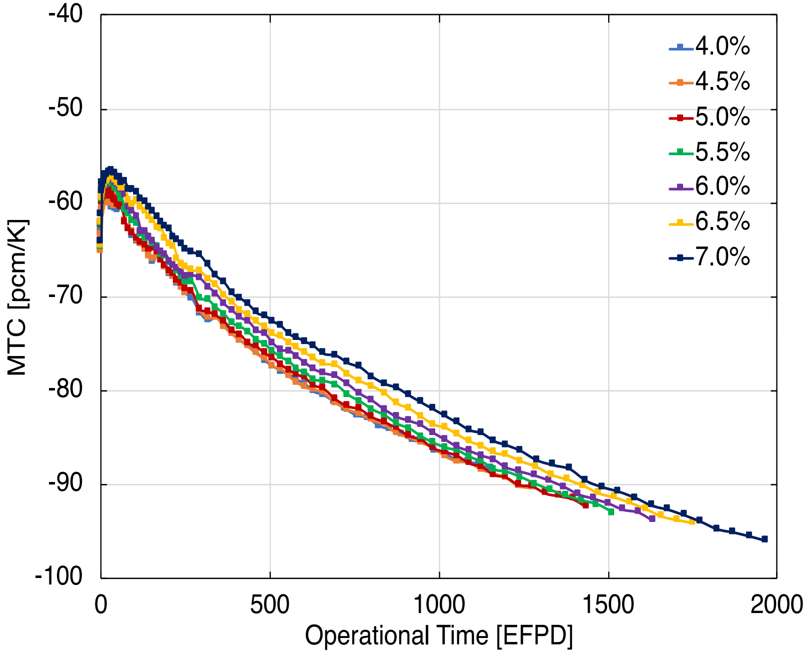
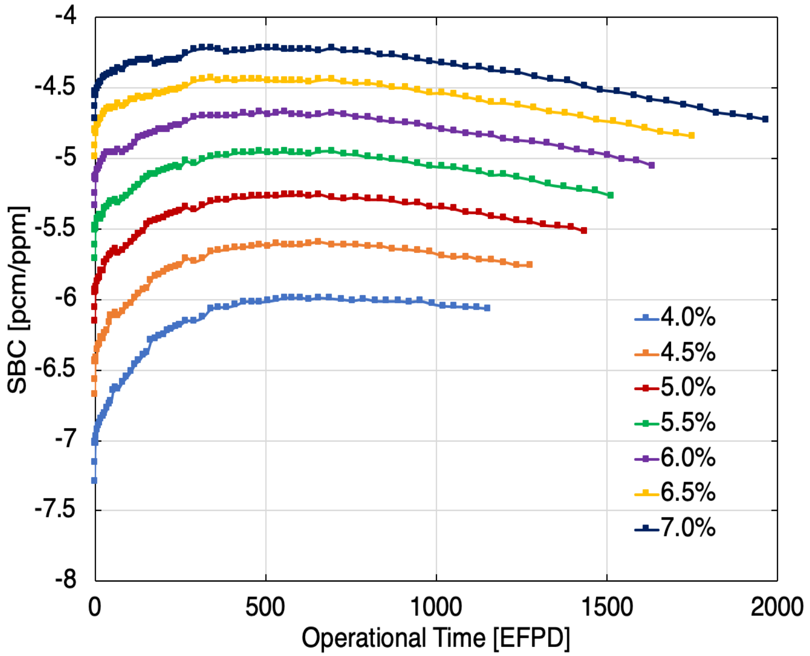
Results: Differences in reactivity coefficients are modest



Fuel Temperature



Coolant Temperature



Soluble Boron

Higher enrichments move reactivity coefficients slightly in the positive direction

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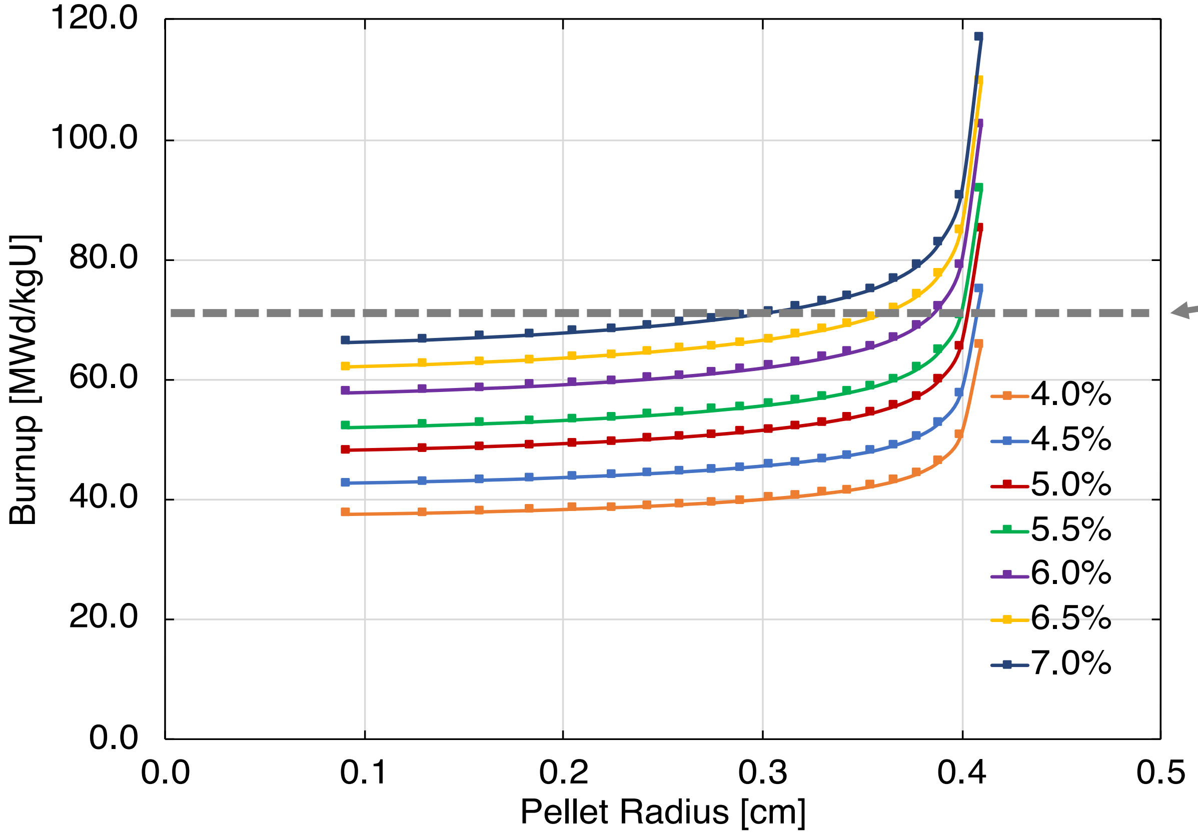
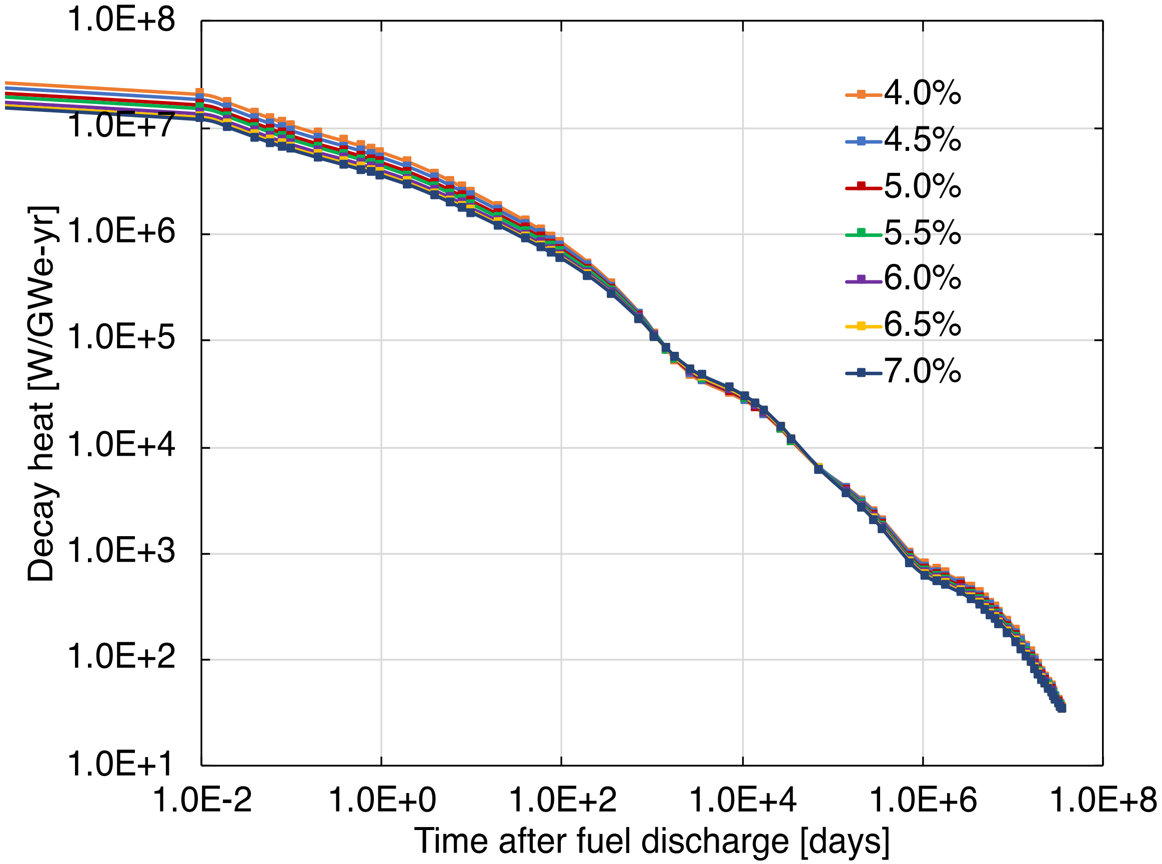
Results: Greater discharge burnups achievable with higher enrichments yield significantly greater local burnup



Implications for fuel pulverization during transients (~71 MWd/kgU threshold)

Results: Differences in spent fuel decay heat are modest



Summary

- A thorough analysis of the reactor physics and fuel cycle impacts of increasing LWR fuel enrichment above 5% was carried out using simple 2D pin cell models in SCALE
- No practical impediments to deploying LWR fuels with enrichments above 5% were identified at this stage
  - Full-core analysis is necessary