UCS Perspectives on Advanced Reactor Fuel Technologies

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New fuels and fuel cycles introduce new challenges

- The NRC should condition license approvals for all stages of advanced reactor fuel cycles on availability of good data, robust analysis, and technical understanding—and impose appropriate operational limits where gaps exist
  - Safety
  - Security
  - Material accounting and proliferation
  - Transportation safety and security
  - Waste management/disposal

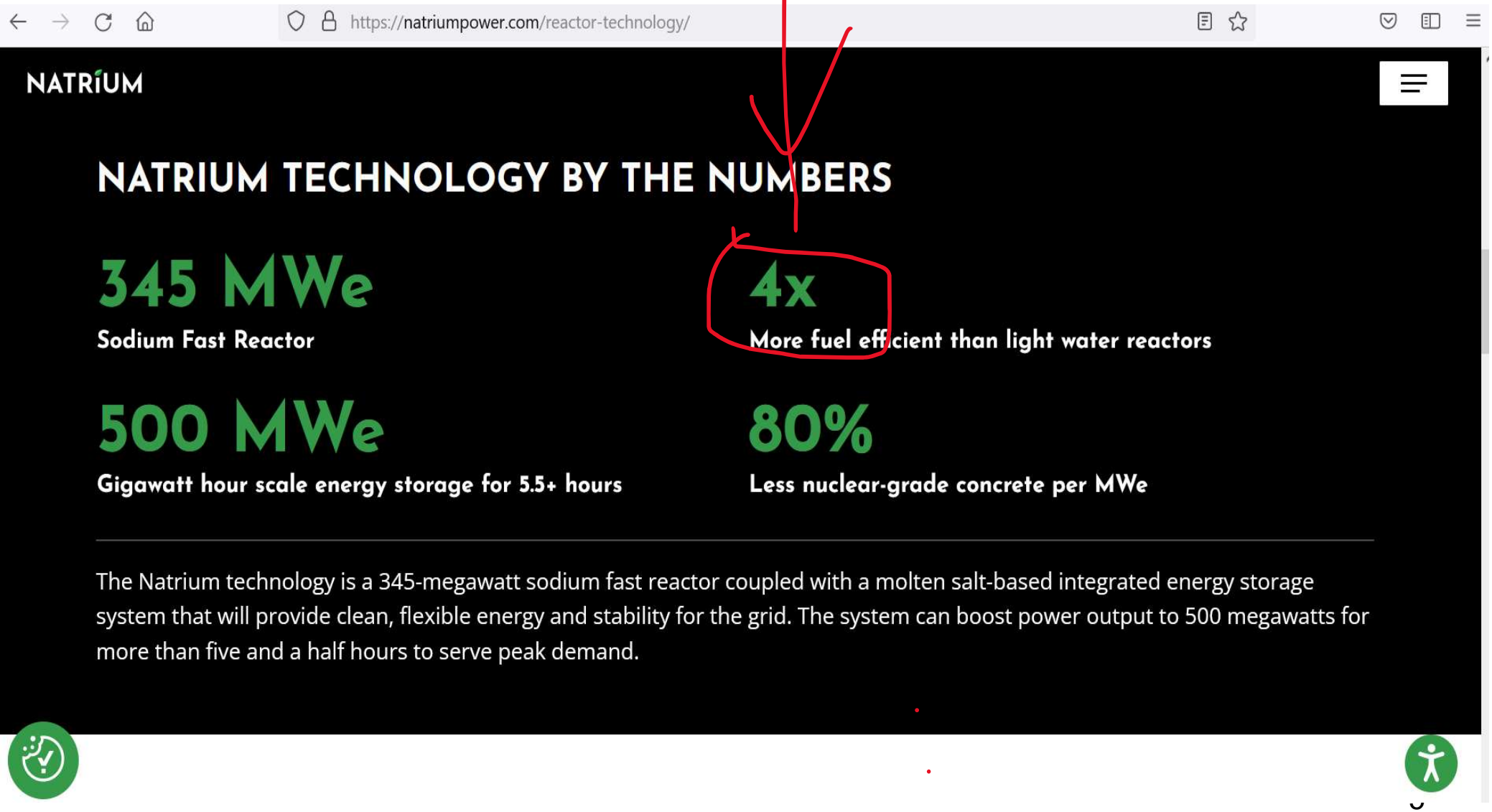
Advanced fuel qualification

- Critical for
  - normal operation
  - design-basis and severe accidents
  - sabotage
  - military attacks (where appropriate)
- Unlike advanced reactor fuels, LWR fuel development has benefited from thousands of reactor-years of operating experience, irradiation under a wide range of operating conditions, out-of-pile and integral accident testing, and data from real events
- Fuel qualification is generally a lengthy and painstaking process, and shortcuts may miss important phenomena
- Modeling and simulation tools need to be well-validated if used to extrapolate beyond existing data envelopes

Too-short timelines

- UCS is concerned that NRC will be pressured to accelerate approvals by using weaker standards for demonstrating fuel performance and developing accident source terms
  - to meet externally mandated, aggressive, arbitrary timelines
  - to allow licensees to push fuel burnups well beyond the limits supported by existing data to improve the poor economics and performance metrics of their designs
- Schedules for deployment of fuel facilities versus reactors will leave little time for qualification of production-scale, as-fabricated fuel
  - TRISO (Kairos, X-Energy, UIUC) (AGR data of limited applicability)
  - Metallic (Natrium) (extruded versus cast)
- Many demonstration reactors will likely serve *de facto* dual roles as test reactors

Implies avg. burnup of 200 GWd/t; > 3 times limit supported by existing data



Safety concerns

- Many approved and proposed regulatory processes for advanced reactors depend on accurate characterization of mechanistic source terms—and hence validated fuel performance during accidents
  - EPZ sizing, limited-scope security, functional containment, LMP
  - Very important when credited for radionuclide retention (TRISO)
  - Also an issue for routine operation of molten-salt-fueled reactors
- Timing of approval of Part 50 construction permits
  - NRC may be asked to approve construction permits for designs without physical containment based on credit for fuel performance that has not been fully validated
  - In such cases, NRC should require demonstration of fuel performance to be part of a construction permit application

Public confidence

- The proprietary nature of much fuel design and performance data severely limits opportunities for public understanding of the technical basis for regulatory decisions
- NRC should reconsider the balance between protecting proprietary information and ensuring the public has access to vital safety information

What the public doesn't see

Table 7-2: Design Basis Criteria and Supporting Information to Predict Fuel Failure

Specific RAC	Acceptance Criterion	Applicable Design Basis Criteria	Available Supporting Data
4.2-2.1	Fuel system design limits shall be established and used for the prediction of fuel pin failure due to overheating of the cladding.	Peak cladding temperature limit	TS
4.2-2.2	Fuel system design limits shall be established and used for the prediction of fuel pin failure due to overheating of the fuel slug.	Peak fuel temperature limit	
4.2-2.3	Fuel system design limits shall be established and used for the prediction of fuel pin failure (loss of cladding integrity) due to deformation of the cladding from mechanical loads.	Cladding strain-thermal creep	
4.2-2.5	Fuel system design limits established and used for the prediction of fuel pin failure (loss of cladding integrity) shall address the effects of cladding wastage.	Cladding Wastage – FCCI	
		Cladding Wastage – Eutectic	
		Cladding Wastage –Na Corrosion	
		Cladding Wastage – Fretting	

The proprietary information is redacted in this document, and is denoted as trade secrets (TS)

Proliferation and nuclear terrorism

- Findings and recommendations from the recently released National Academies study on different fuel cycles and technology options (NASEM, 2022)
  - "Expanding the global use of HALEU would potentially exacerbate proliferation and security risks because of the potentially greater attractiveness of this material for nuclear weapons compared with the low-enriched uranium used in light-water reactors." (Finding 19)
  - "Fuel cycles involving reprocessing and separation of fissile materials that could be weapons usable pose greater proliferation and terrorism risks than the once-through uranium fuel cycle with direct disposal of spent fuel … [including] fissionable materials other than the 'traditional' special nuclear materials …" (Finding 20)

Proliferation and nuclear terrorism (cont.)

– "The NRC should initiate a rulemaking to address the security and material accounting measures for HALEU and other attractive nuclear materials that may be present in advanced reactor fuel cycles" (Recommendation O)

National Academies of Sciences, Engineering, and Medicine. 2022. *Merits and Viability of Different Nuclear Fuel Cycles and Technology Options and the Waste Aspects of Advanced Nuclear Reactors.* Washington, DC: The National Academies Press. Https://doi.org/10.17226/26500

Proliferation and nuclear terrorism (cont.)

- The shift from LWR LEU to HALEU raises proliferation and terrorism concerns because of the
  - increased attractiveness of HALEU
  - increased incentive to reprocess the spent fuel may stem from aforementioned poor performance metrics for HALEU-fueled reactors and the cost/scarcity of HALEU

Acronyms

- **AGR: Advanced Gas Reactor**
- **EPZ: Emergency Planning Zone**
- **HALEU: High-Assay Low-Enriched Uranium**
- **LMP: Licensing Modernization Project**
- **TRISO: Tristructural Isotropic**
- **UCS: Union of Concerned Scientists**
- **UIUC: University of Illinois Urbana-Champaign**