Update on U.S. Recycling Activities of Used Nuclear Fuel (UNF)

Vermont Nuclear Decommissioning Citizens Advisory Panel
Federal Nuclear Waste Policy Committee

Sven Bader

June 12, 2023

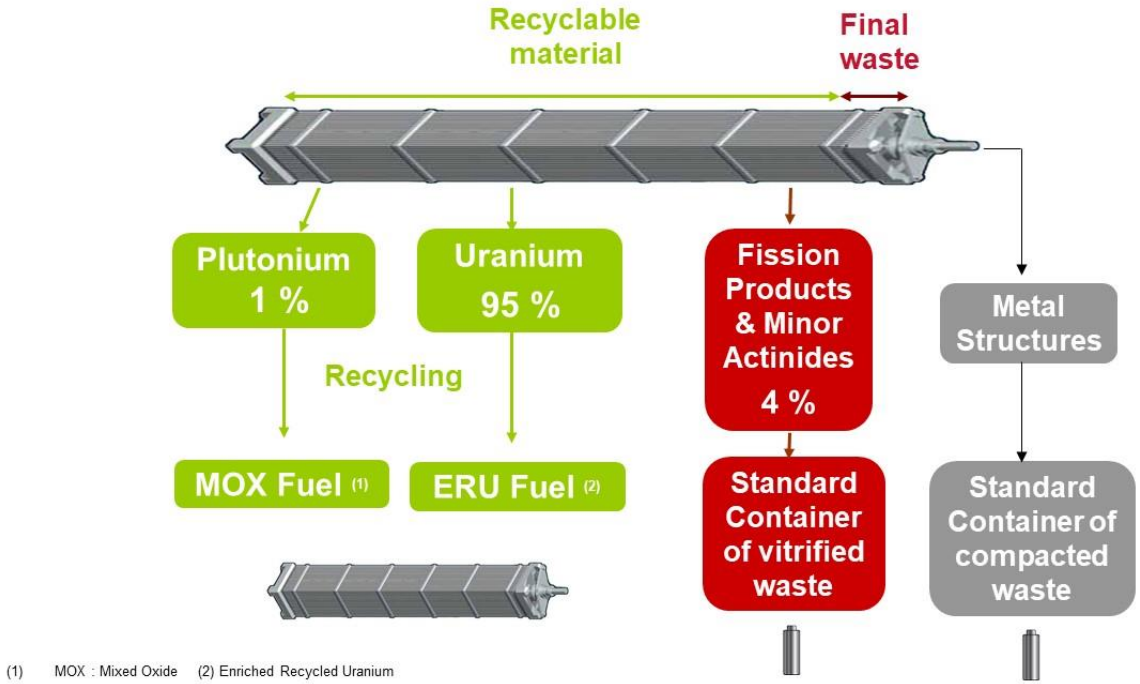
orano

Agenda

1. What is recycling of used nuclear fuel (UNF)?
2. Classic Recycling
3. French Impact of Recycling
4. Nuclear Energy Institute's Recycling Principles
5. Status of Recycling in the U.S.
6. What about Recycling Old, Cold Used Fuel?
7. Linked Activities
8. Advanced Recycling Activities
9. Conclusions

What is Recycling of UNF? Start with Fuel…

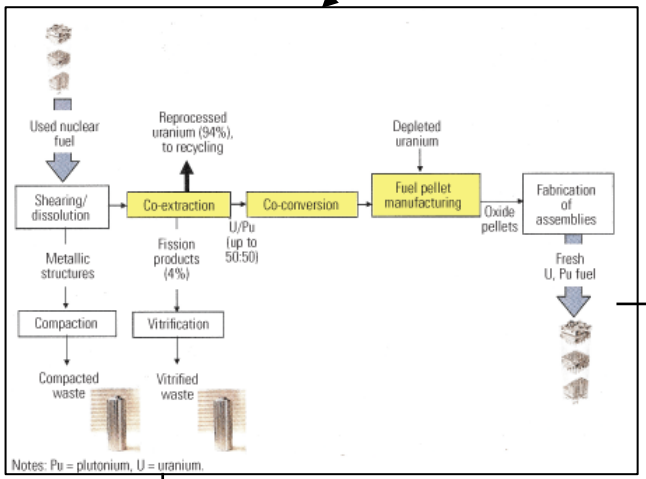
Spent Nuclear Fuel – fuel destined for disposal
Used Nuclear Fuel – fuel with value that could be reused

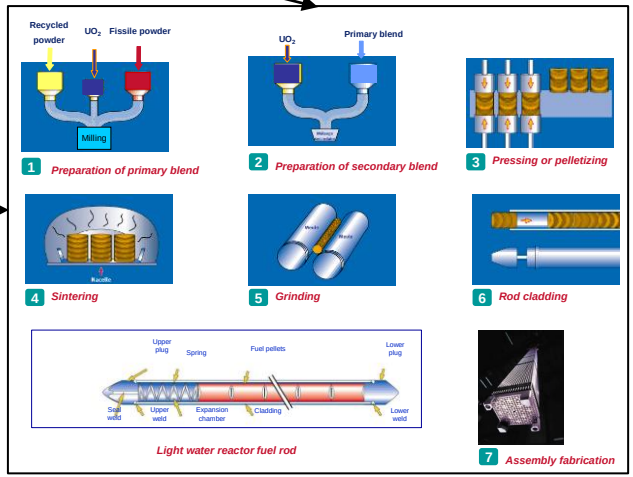


(1) MOX : Mixed Oxide (2) Enriched Recycled Uranium

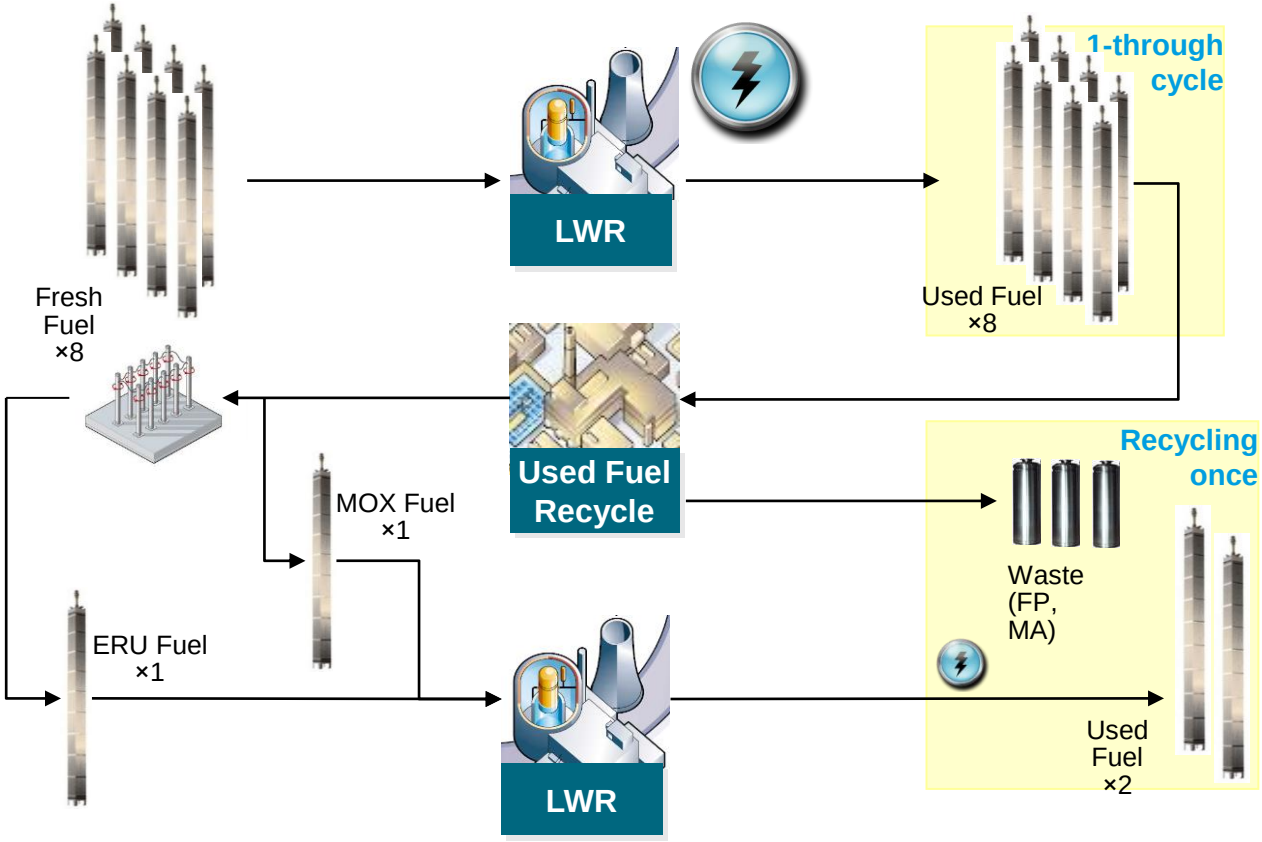
What is Recycling of UNF?

Recycling = Reprocessing + Fuel Fabrication

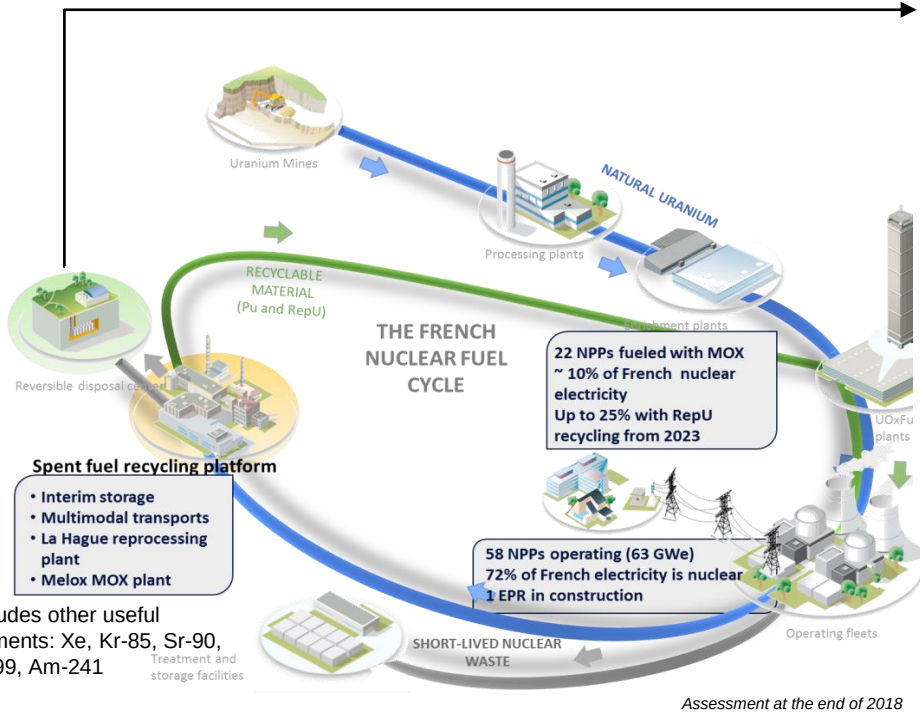




Classic Recycling of UNF

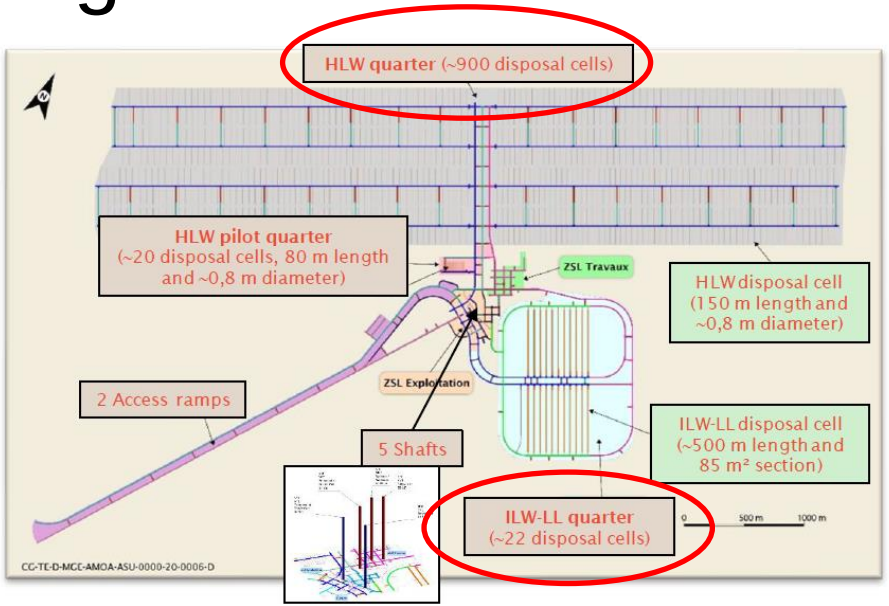


French Impact of Recycling



Includes other useful elements: Xe, Kr-85, Sr-90, Tc-99, Am-241

Assessment at the end of 2018



Repository Impact

Re-use of used MOX fuel performed with Borssele (Netherlands) NPP to be presented at ANS Wednesday.

Nuclear Energy Institute's Recycling Principles

- Recycling would not replace the need for disposal in a geologic repository
- Recycling technologies should further clean energy and sustainability goals
- Recycling technologies should increase the economic competitiveness of future nuclear reactors
- Recycling should help improve U.S. energy security
- The U.S. should support research, development, and demonstration of used nuclear fuel recycling technologies
- Recycling technologies should avoid unacceptable proliferation risks
- The NRC should license recycling facilities under its current regulations and implement innovative approaches to achieve timely reviews of recycling facilities

Status of Recycling in the U.S.

Commercial Recycling/Reprocessing

- Permitted in the U.S. and regulated under 10CFR50 (though some Federal agencies are somewhat unsupportive)

Current U.S. Policy Structure Focused on Once-Through Fuel Cycle

- NWPA, Standard Contract, Repository Program

Department of Energy continues to Support R&D

- Advanced Research Projects Agency − Energy (ARPA-E) CURIE
- ARPA-E ONWARDS
- Office of Materials Recovery and Waste Management (NE-43) is recycling EBR-II SNF at INL to produce HEU for down blend to HALEU for advanced reactors

Recent Commercial Interest

- Shine, Curio, Oklo, Moltex

What about Recycling Old, Cold Used Fuel?

Almost all the U and Pu contained in this fuel is relatively stable (only the Pu-241 unfortunately has decayed away – it is a valuable fuel for reactors) and suitable for recycling into:

- MOX fuel for LWRs
- HALEU-equivalent MOX, U+Pu metal, and/or U+Pu salt fuel for advanced reactors

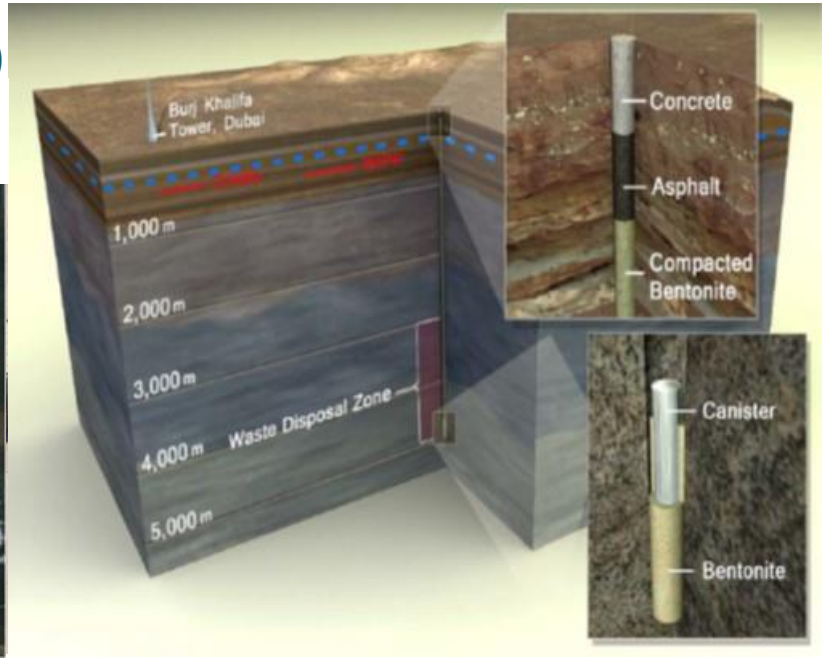
Majority of the Kr-85 has decayed away and hence avoids the need (40CFR190) for placement of expensive off-gas treatment processes for reprocessing plants and avoids the need for decay storage of captured Kr-85

Short lived radionuclides will have decayed away and hence:

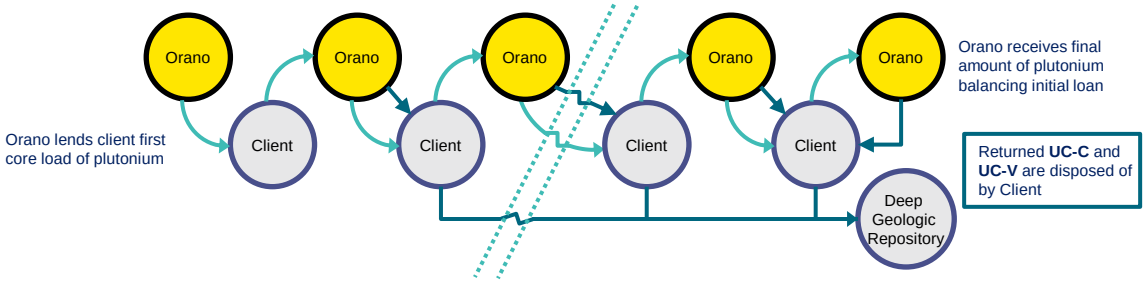
- Promote the separation of some valuable stable elements/isotopes (e.g., Xe) as the associated radioisotopes have decayed away
- Potentially allow for higher loading in the vitrification waste forms of the remaining fission products
- Potentially reduce the amount of shielding required for the separations processes
- Potentially reduce the cooling requirements for the raffinates
- Reduces the amount of radiolytic produced hydrogen
- Reduces the amount of radiolytic damage to organics in the process (and hence reduces the amount of waste)

Linked Activities…

- **Deinventory Studies (site-specific for VY is now in progress)**
- **Transportation (Atlas Railcar, Transportation Cask, Consent Based Transport)**
- **Transload (Rail to Truck)**
- **Consolidated Interim Storage**
- **Disposal (fillers for direct disposal, DBH)**

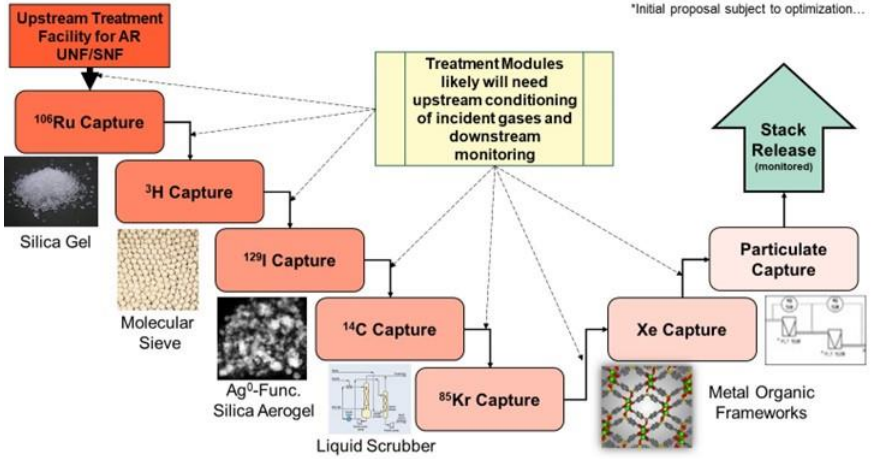


Advanced Recycling: Recycling Used MOX, Take-Back Program with Advanced Reactors, Isotope Recovery, Advanced Separations, ARPA-E



The Solution… a modular "plug-n-play" treatment system*

*Initial proposal subject to optimization…



Conclusions

- **Challenges Continue to Exist to Recycling UNF including:**
- Cost
- Licensing
- Proliferation
- Wastes
- Policy Certainty

- **However, the Incentives are Tangible**
- Enhances security of fuel supply & may resolve HALEU issue for advanced reactors
- Improve design of repository (no criticality, standard highly stable waste form, reduced HLW volume)
- Natural resources savings (25% mining savings)
- Supports non-proliferation objectives (stabilizes or reduces total Pu inventory & degrades Pu vector)
- Positive economic and social impacts (thousands of jobs)
- Improves public acceptance of nuclear energy (less indefinite storage of UNF)

- **Difficult to cover all in ~20 minutes, but ask away…**

orano

ARPA-E ONWARDS

Optimizing Nuclear Waste and Advanced Reactor Disposal Systems

ONWARDS goals

- Recycling of advanced reactor UNF into fuel for advanced reactors
- Develop/demonstrate breakthrough technologies that facilitate 10x reduction in AR waste volume generation or repository footprint
- Advance development of high-performance AR waste forms while maintaining exemplary safeguards standards and global back-end costs in the accepted range of 1¢/kilowatt-hour (kWh)

Awards

- $36M for 11 projects
- Brigham Young University, Citrine Informatics, Deep Isolation, GE, INL, Oklo, Orano Federal Services, Rutgers University, Rensselaer Polytechnic Institute, Stony Brook University, TerraPower

ARPA-E CURIE

Converting UNF Radioisotopes Into Energy

CURIE goals

- Recycling of LWR UNF into fuel for advanced reactors
- Develop innovative separations technologies, material accountancy, and online monitoring technologies, and designs for a reprocessing facility that will enable group recovery of actinides for AR feedstocks
- Incorporate in-situ process monitoring, minimize waste volumes, and maintain disposal costs ~1¢/kWh

Awards

- $38M for 12 projects
- ANL (2), INL, CURIO, GE Research, EPRI, Mainstream Engineering, NuVision Engineering, University of Alabama at Birmingham, University of Colorado, University of North Texas (Denton, TX), University of Utah (Salt Lake City, UT)