Fuel Cycle Based on Integral Fast Reactor and Pyroprocessing

International Symposium
Present Status and Future Prospective for Reducing Radioactive Waste
-- Aiming for Zero Release --

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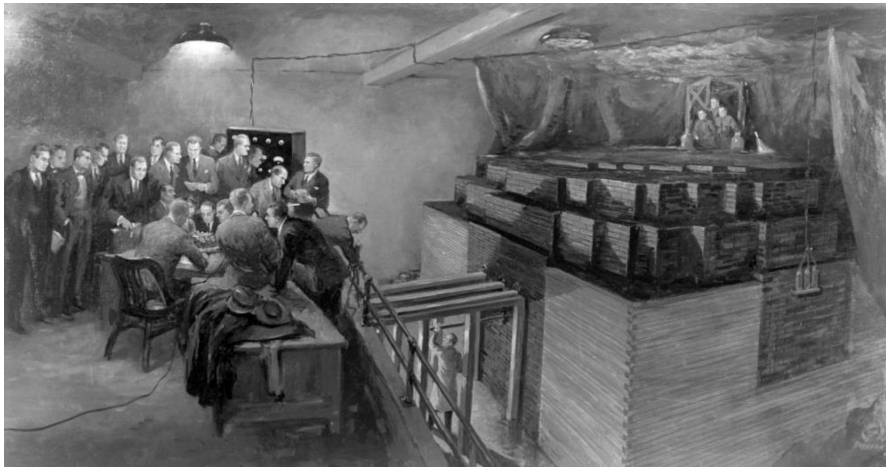
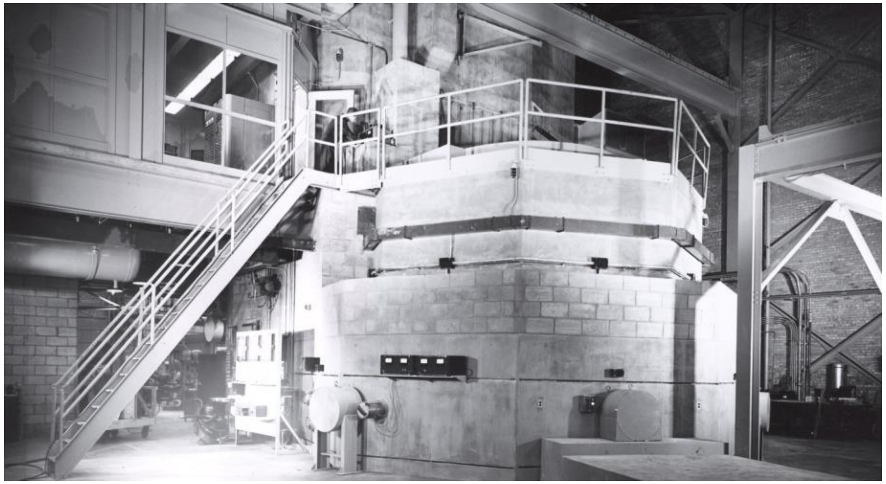
Argonne Has Been a Pioneer of Nuclear Energy

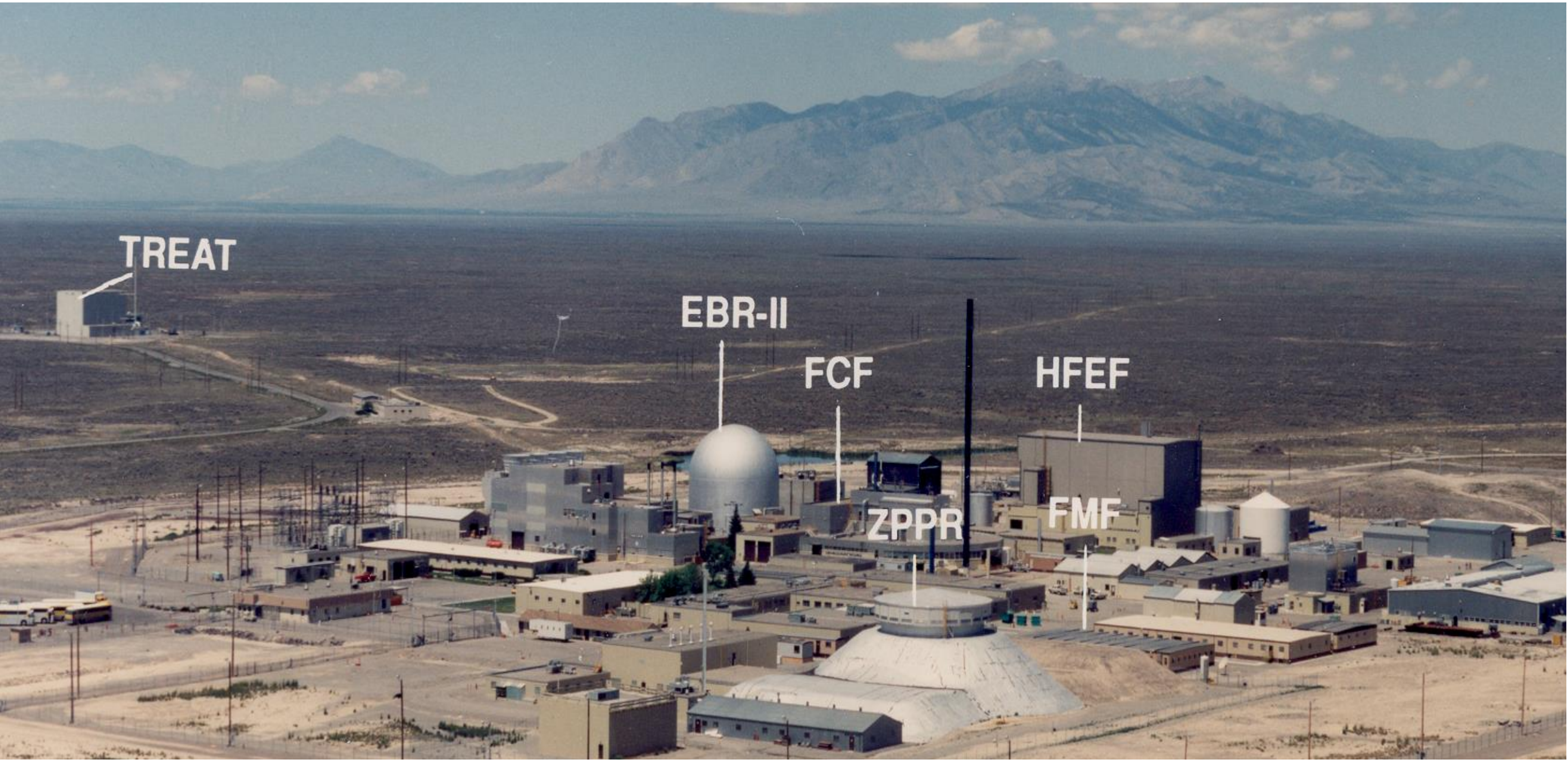
- Enrico Fermi and his team achieved the first controlled chain reaction in Chicago Pile-1 (CP-1): December 2, 1942.
- Enrico Fermi first introduced the fast reactor idea in 1944 and Walter Zinn completed a concept design in 1946.
- Experimental Breeder Reactor-I (EBR-I) started operation in 1951, producing the first electricity from nuclear, and demonstrated the breeding principle in 1953.





Experimental Breeder Reactor-II (EBR-II)

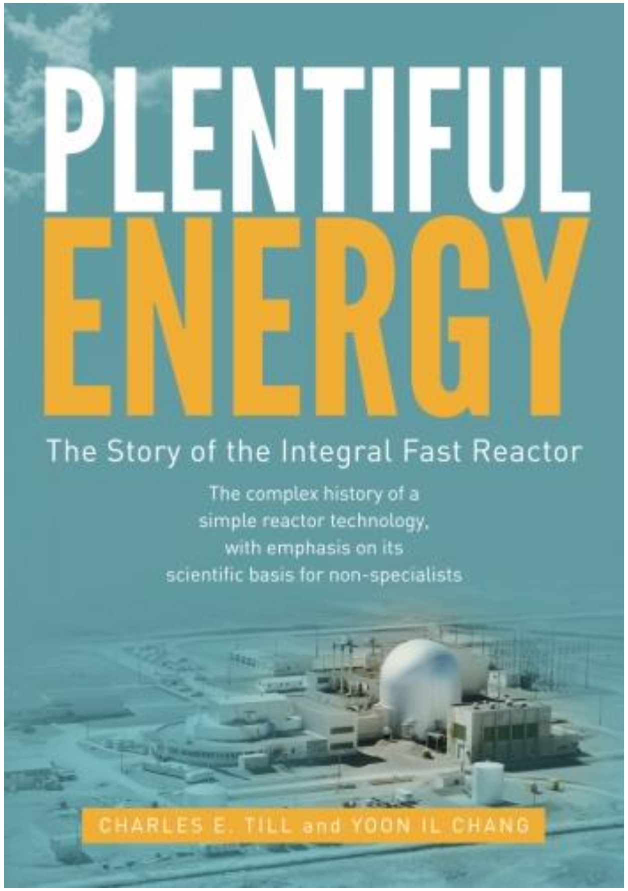
- First pool-type fast reactor, started operation in 1964
- Fuel cycle closure demonstration during 1965-69
- Inherent safety demonstration in April 1986



Argonne-West facilities, now merged into Idaho National Laboratory

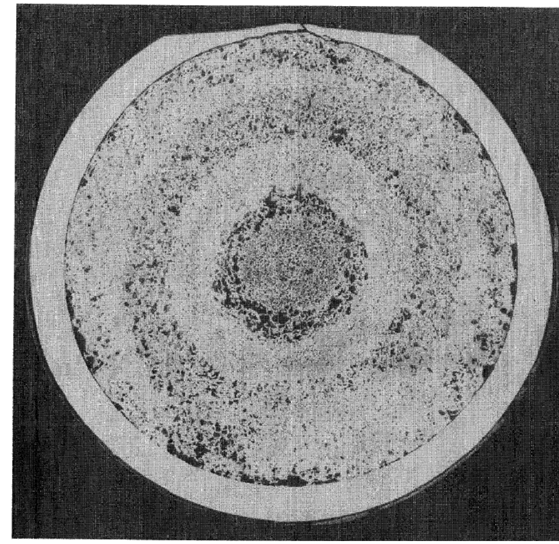
The Integral Fast Reactor (IFR)

- Developed at Argonne National Laboratory (1984-1994) as a next-generation reactor concept.
- Key innovations: metal fuel and pyroprocessing
  - Uranium resource utilization is improved by a factor of 100 compared to current commercial reactors, making nuclear almost limitless energy source.
  - Unique inherent passive safety has been demonstrated.
  - Lifetime of radiological hazard of nuclear waste is reduced from ~300,000 years to ~300 years.
  - Proliferation-resistant and economic fuel cycle closure based on pyroprocessing.

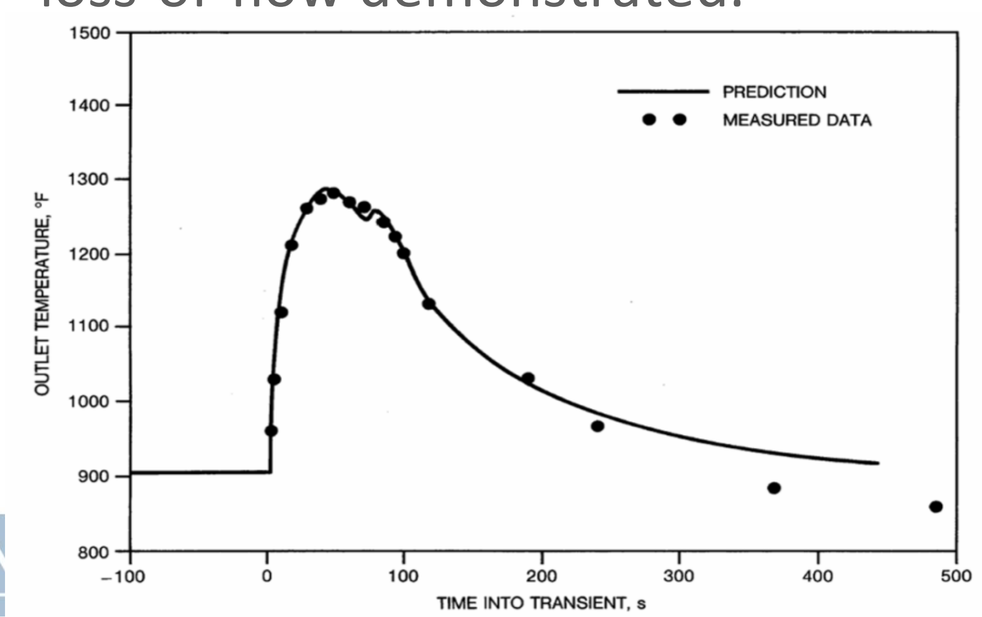


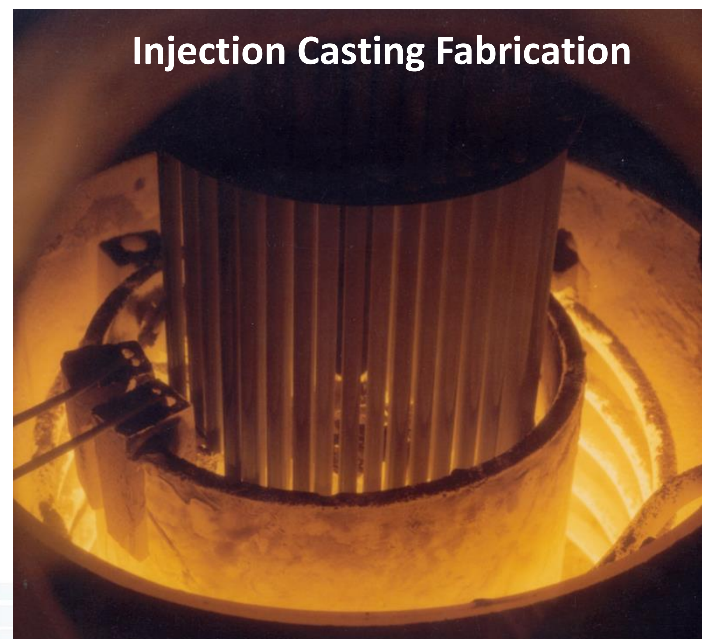
Metal Fuel Performance

- Reliable >20% burnup demonstrated
- Superior Run-Beyond-Cladding-Breach performance
- Injection-casting fabrication is simple and remotization of actinide containing fuel is straightforward.
- Inherent safety potential for unprotected loss-of-flow demonstrated.

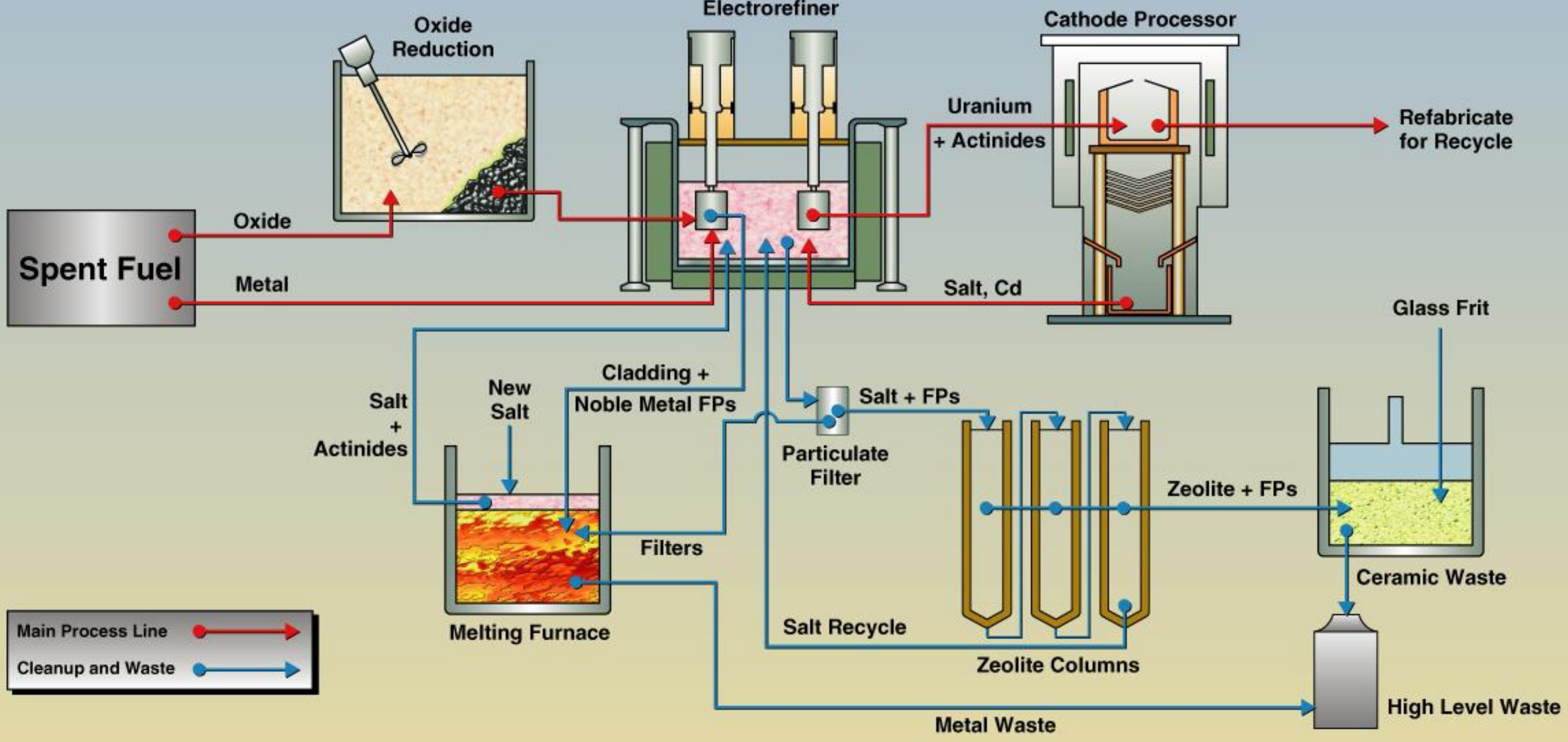


12% Burnup Metal RBCB Test
(Operated 169 days after breach)



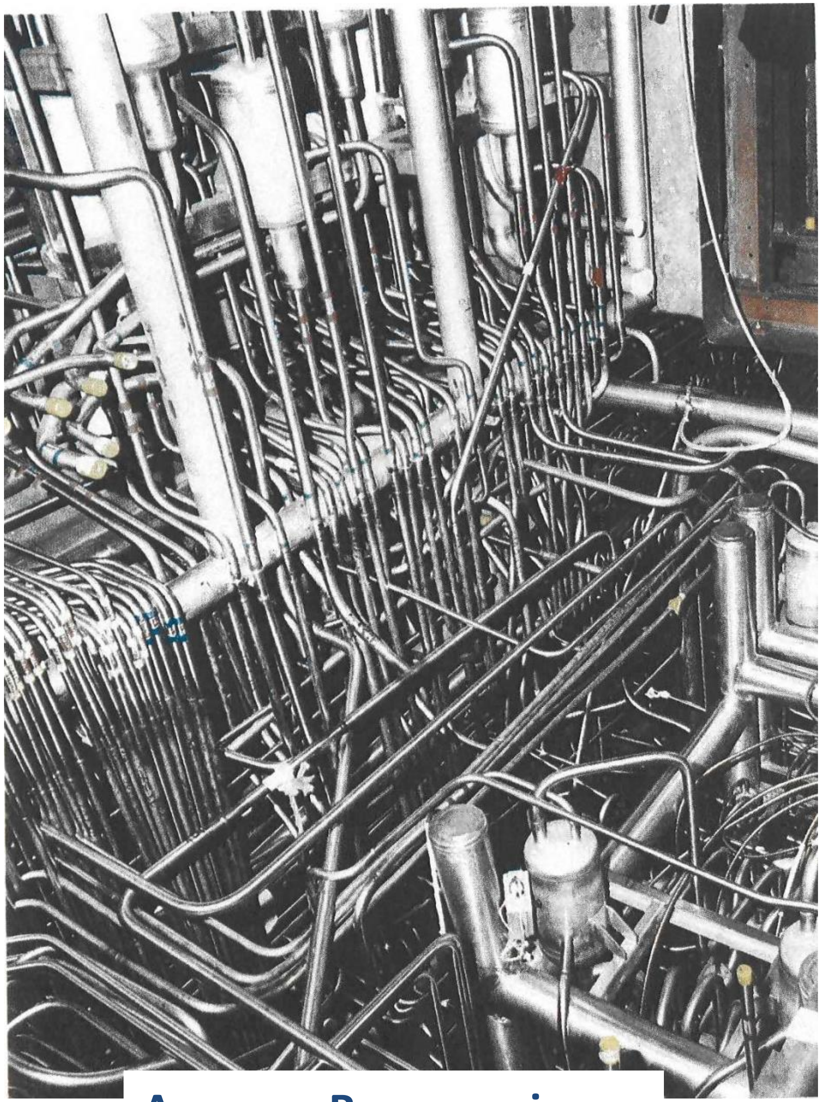


Pyroprocessing Flowsheet



Pyroprocessing equipment and facility are compact
More favorable capital cost and economics

Pyroprocessing

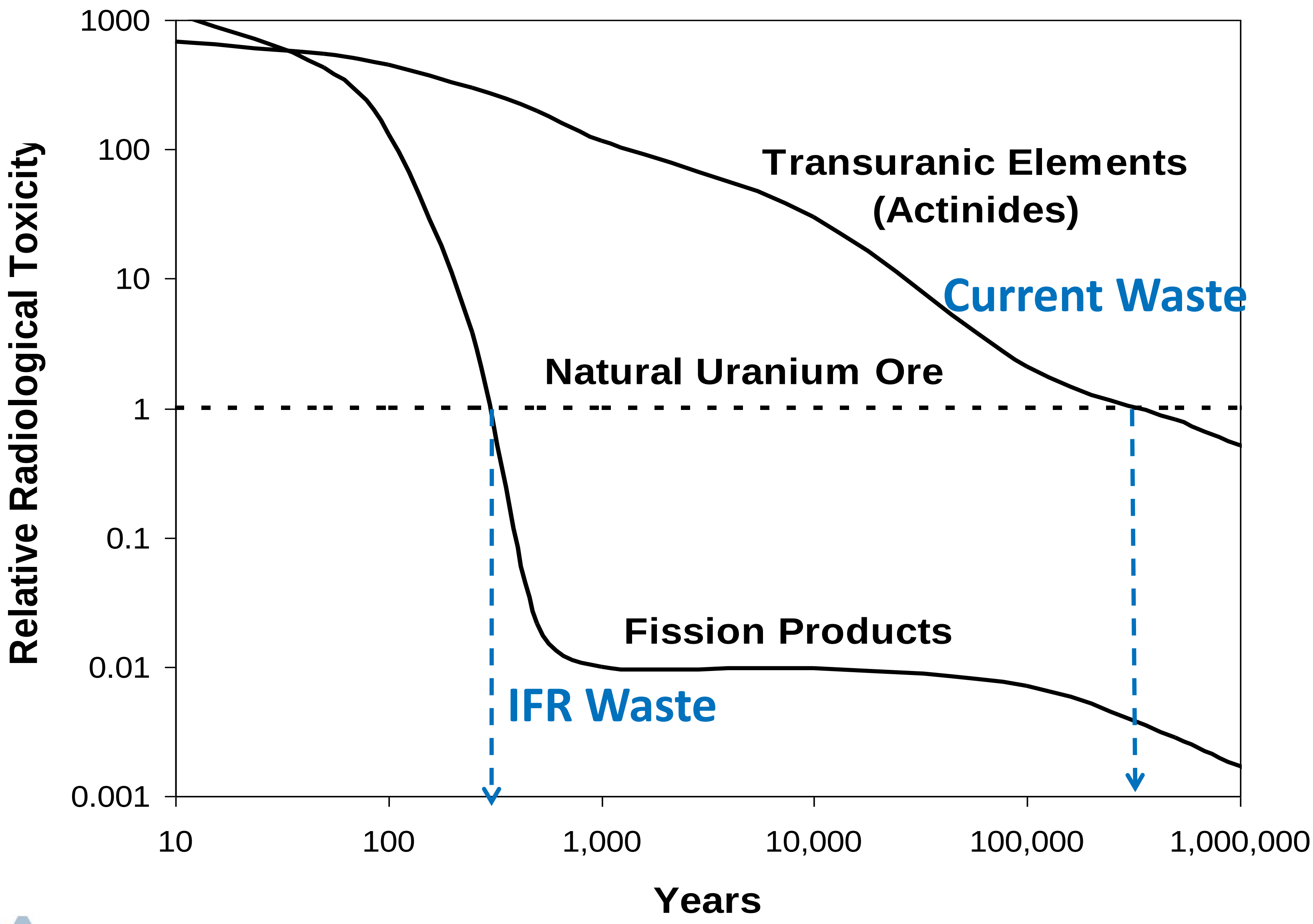


Aqueous Reprocessing

Weapons Usability Comparison

	Weapon Grade Pu	Reactor Grade Pu	IFR Grade Actinide
Production	Low burnup PUREX	High burnup PUREX	Fast reactor Pyroprocess
Composition	Pure Pu 94% Pu-239	Pure Pu 65% Pu-fissile	Pu + MA + U 50% Pu-fissile
Thermal power w/kg	2 - 3	5 - 10	80 - 100
Spontaneous neutrons, n/s/g	60	200	300,000
Gamma rad r/hr at ½ m	0.2	0.2	200

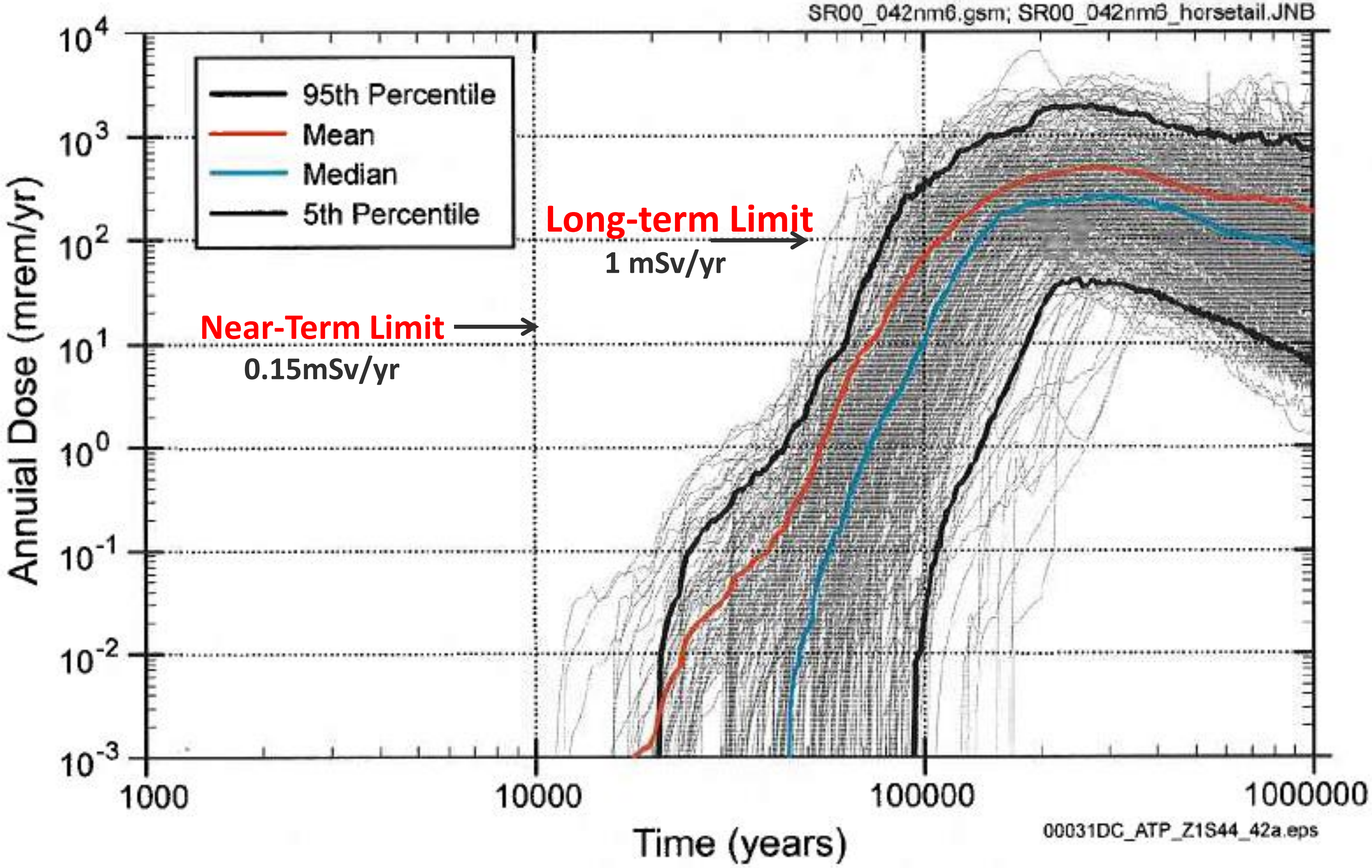
Radiological Toxicity of LWR Spent Fuel



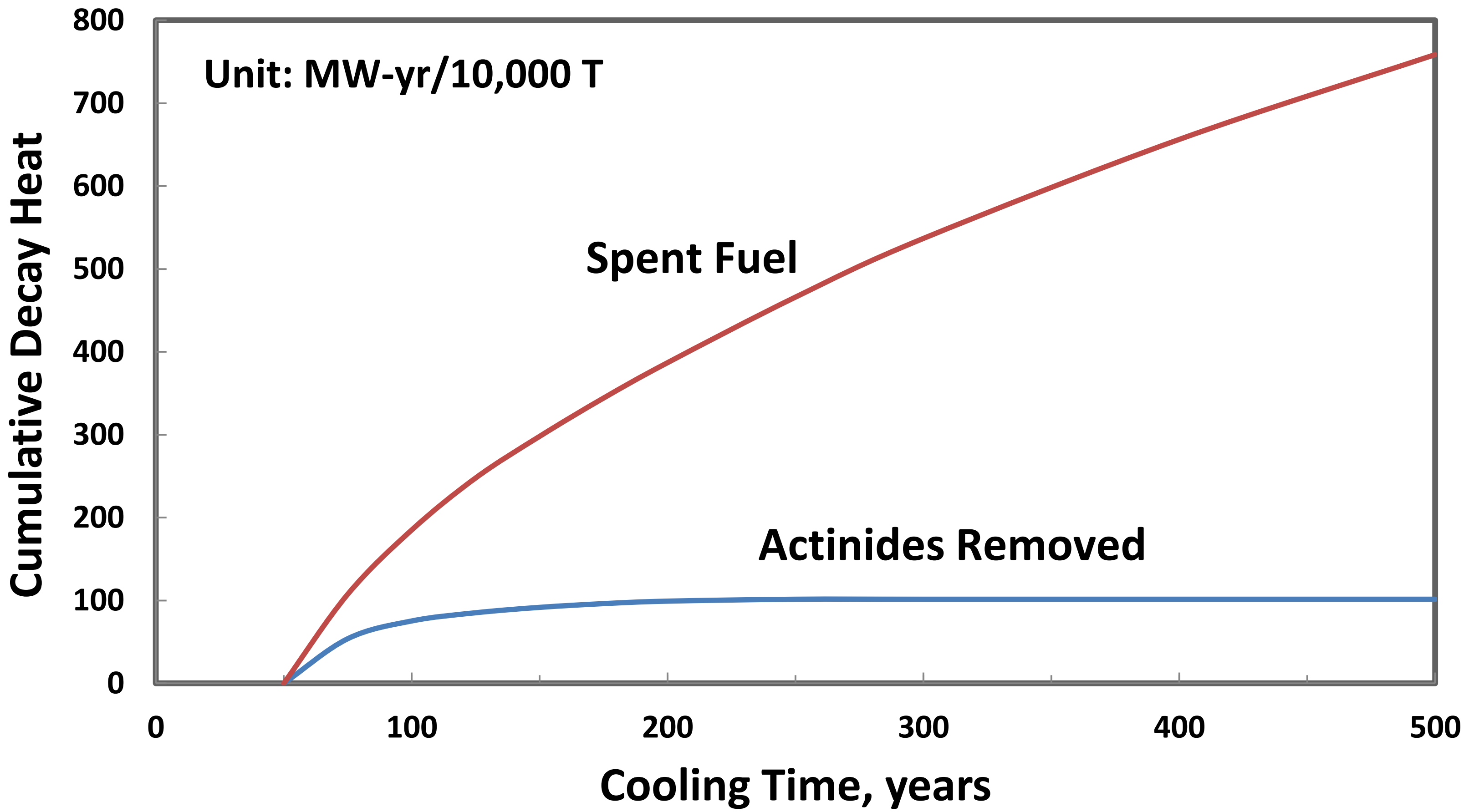
LWR Spent Fuel Radioactivity Normalized to EPA Cumulative Release Limits

Radio-nuclide	Activities at 10 years	Activities at 1,000 years	Activities at 10,000 years
Sr-90	60,000	0.0	0.0
Cs-137	90,000	0.0	0.0
I-129	0.3	0.3	0.3
Tc-99	1.4	1.4	1.4
Other F.P.	1,050	5.1	4.4
Actinides	76,000	19,000	4,000

Long-term Release from Repository



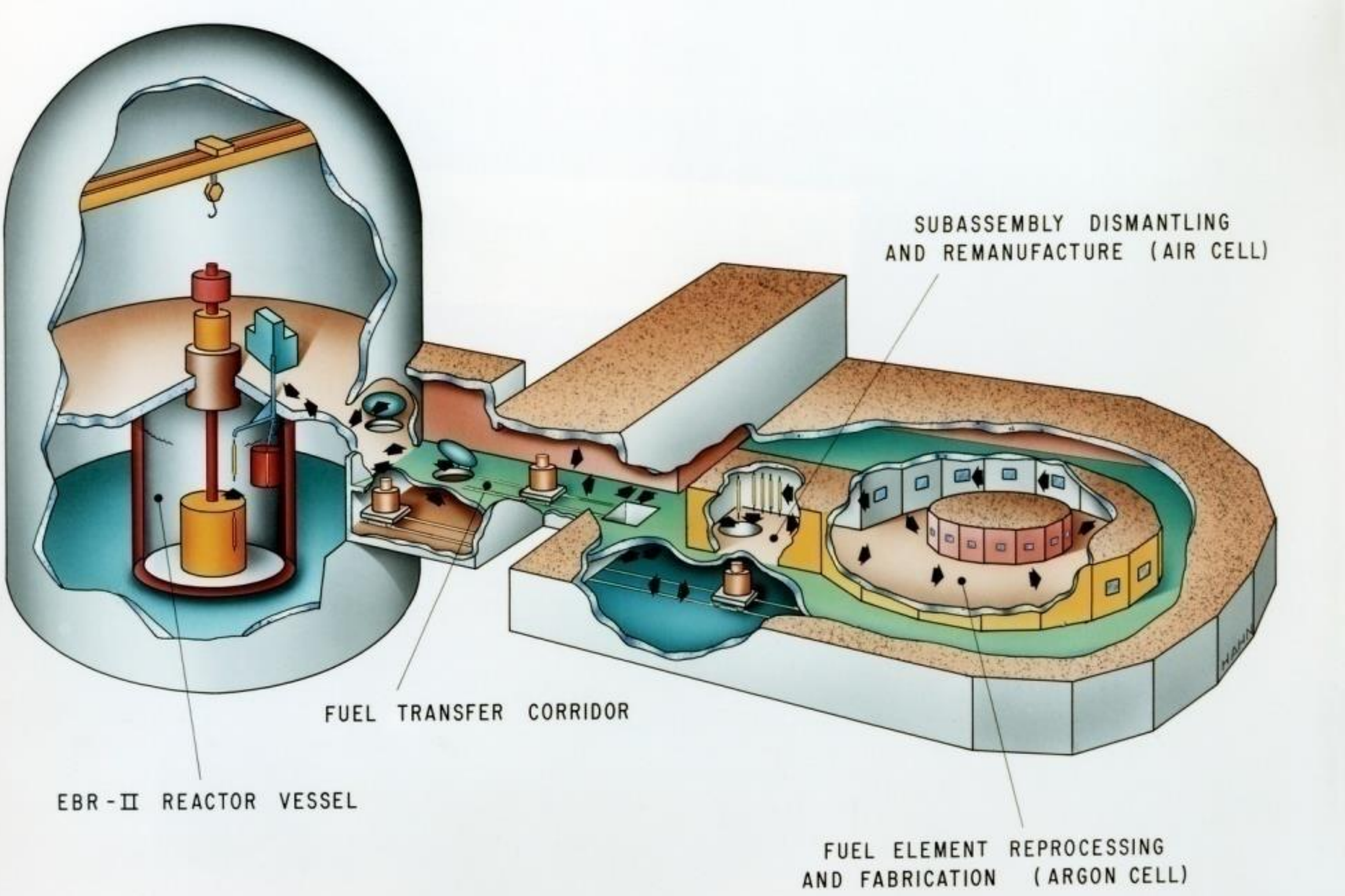
Actinide Removal Allows 5-10 Times More Spent Fuel Disposal for a Given Repository Space



Key Conclusions on Spent Fuel Management

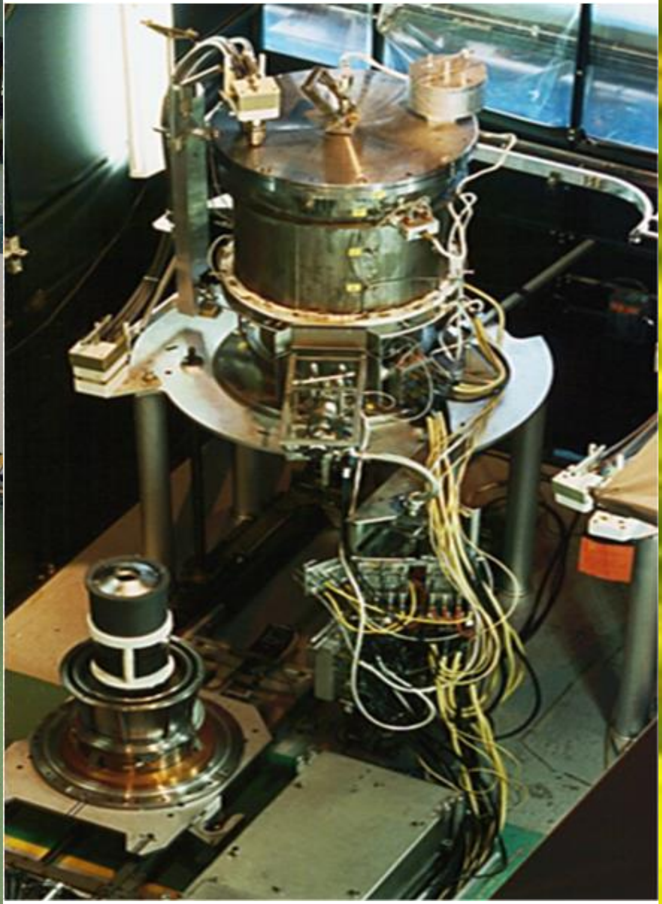
- All 3 different approaches (radiological toxicity, EPA Standards, and repository performance assessment) indicate that a factor of 500-1,000 reduction of actinides (or 99.5-99.9% removal) would be essential for the long-term nuclear waste disposal:
  - Repository requirements can be met on *a priori* basis without the source term.
  - It is our responsibility to free our future generations from the burden of radioactive nuclear waste legacy.
  - Spent fuel is not the best waste form and removing actinides is technologically the best option.
- However, there are two questions raised:
  - Do we have a feasible and economically viable technology?
  - Can we transmute the actinides recovered from the spent fuel?

The original EBR-II FCF was refurbished with electro-refining based pyroprocessing equipment systems



Engineering-Scale Equipment Demonstrated

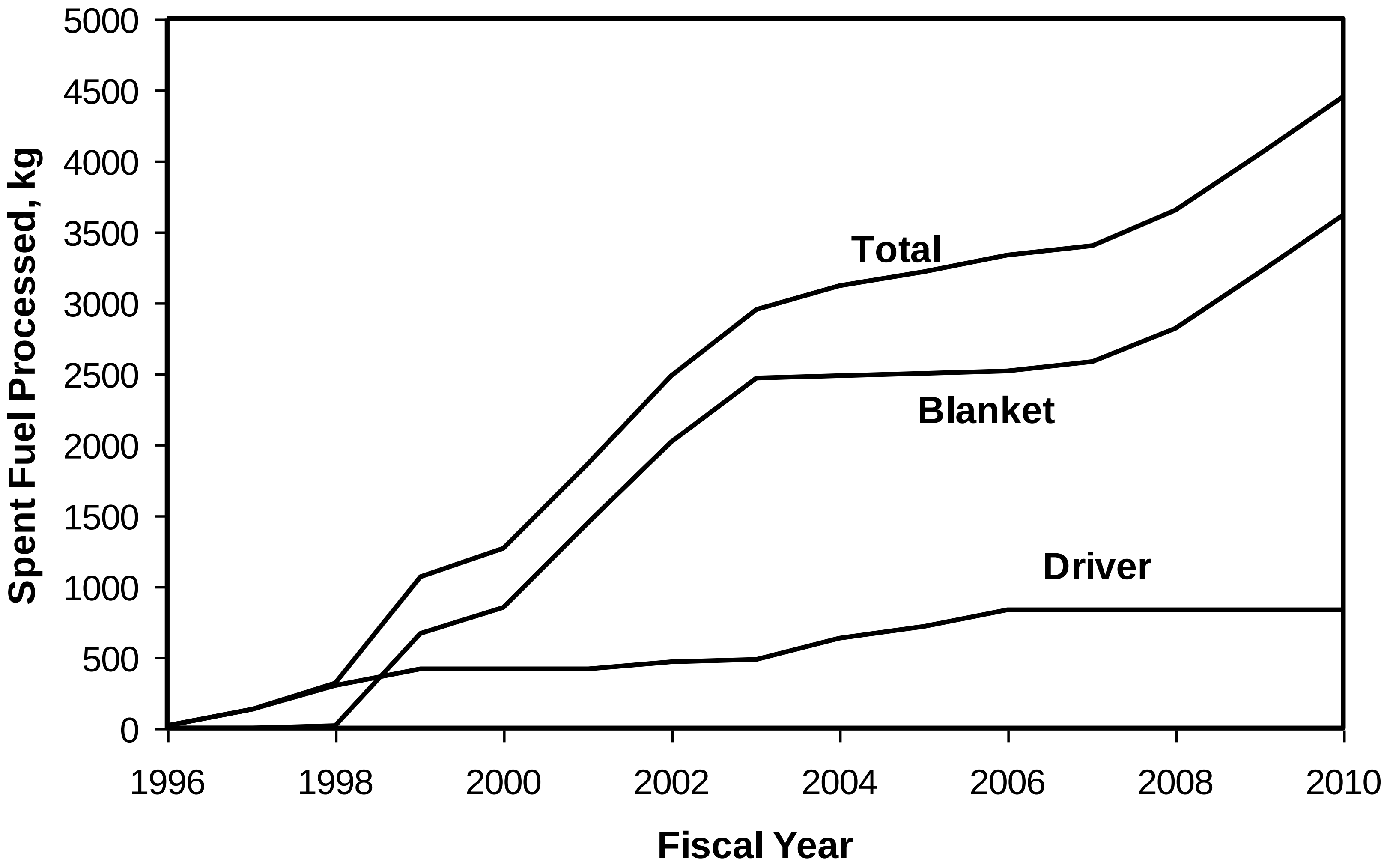
Electrorefiner



Cathode Processor

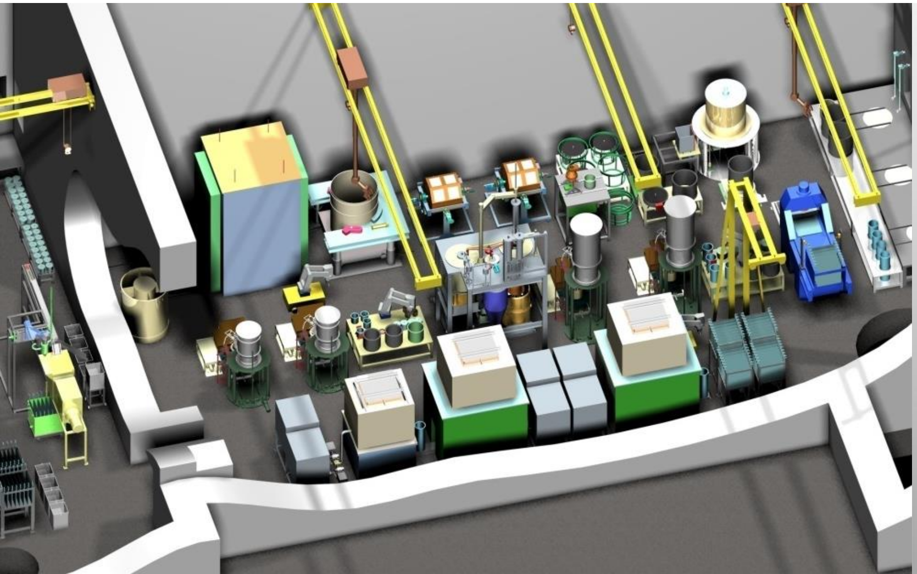
Metal Waste Furnace

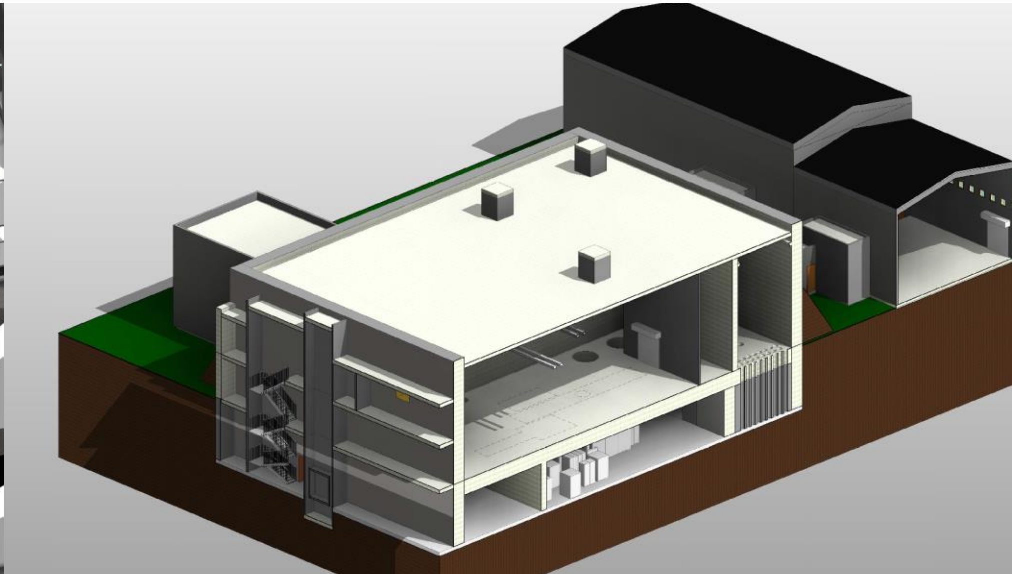
Engineering-Scale Pyroprocessing Has Been Successfully Demonstrated Through EBR-II Spent Fuel Treatment



Pilot-scale (100 T/yr) Pyroprocessing Facility for LWR Spent Fuel

- For pyroprocessing of LWR spent fuel, a front-end oxide to metal conversion and a scale-up of batch size are required.
- The technology feasibility has been established and ANL is currently developing a conceptual design of a pyroprocessing facility for the purpose of engineering details and capital and operating cost estimates.
- If cost estimate is reasonable, a pilot-scale demonstration of a regional solution for spent fuel management can be envisioned.





Summary

- The public views adequate nuclear waste management as a critical linchpin in further development of nuclear energy. Nuclear energy has been utilized over a half century without a definite solution to the back end of the fuel cycle. Examples of metaphors:
  - "Building a house without a toilet!"
  - "A plane taking off without its landing gear!"
- Interim storage is obviously a near-term imperative but should be pursued consistent with a longer-term roadmap, which has a higher priority.

> "If you don't know where you are going, you'll end up someplace else." -- Yogi Berra

- The longer-term roadmap should be developed in a systems approach including the next-generation reactor options.