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Advanced Spent Fuel Processing Technologies for the Global Nuclear Energy Partnership

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9th IEM on Actinide and Fission Product Partitioning and Transmutation
Nîmes, France
27 September 2006

Global Nuclear Energy Partnership

U.S. Department of Energy

THE UNIVERSITY OF CHICAGO

Office of Science
U.S. DEPARTMENT OF ENERGY

A U.S. Department of Energy laboratory managed by The University of Chicago

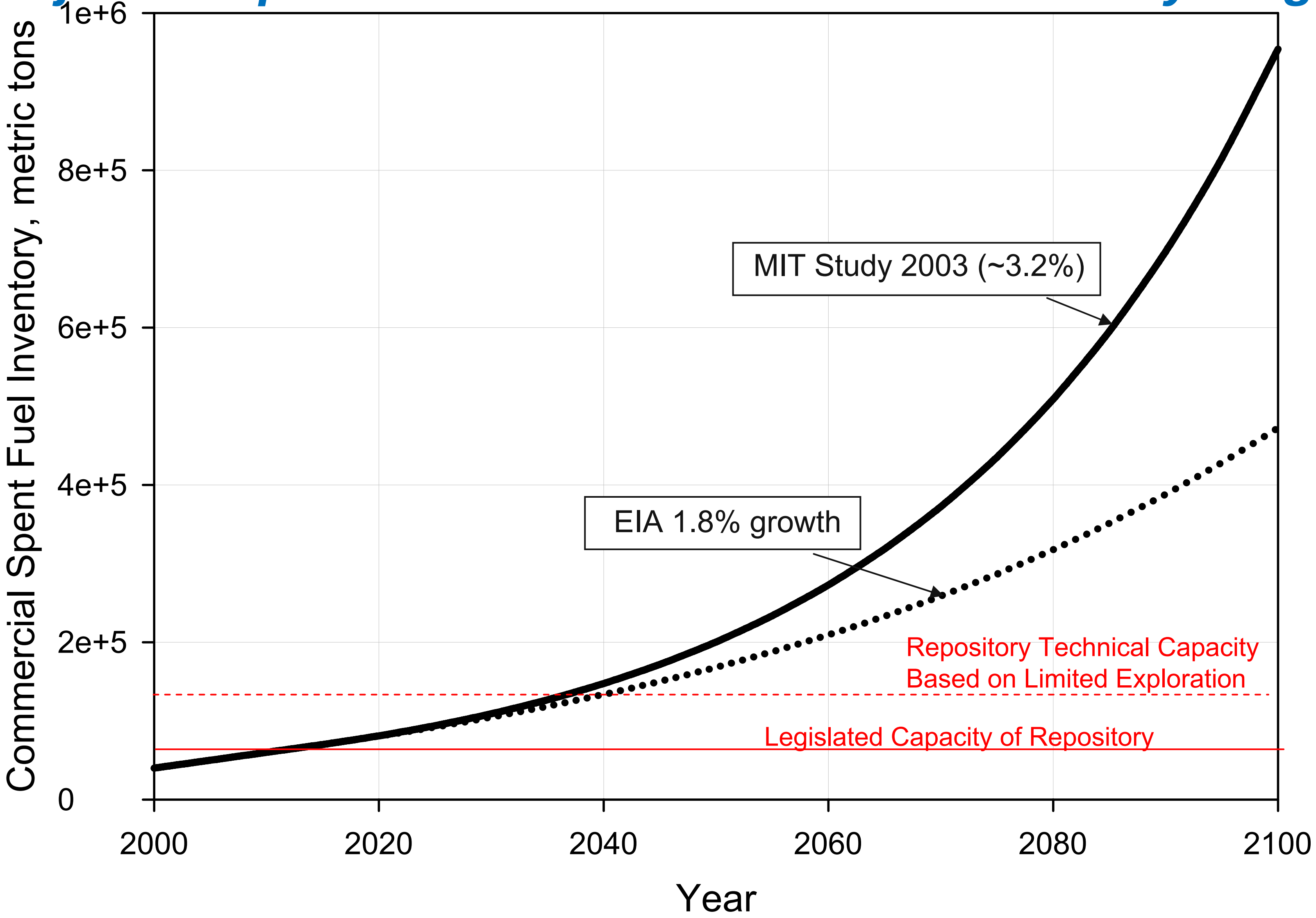
Elements of GNEP: Reprocessing

- Fuel leasing and take-back by supplier nations for reprocessing
- No separated plutonium
- Deployment after 2020 in the United States

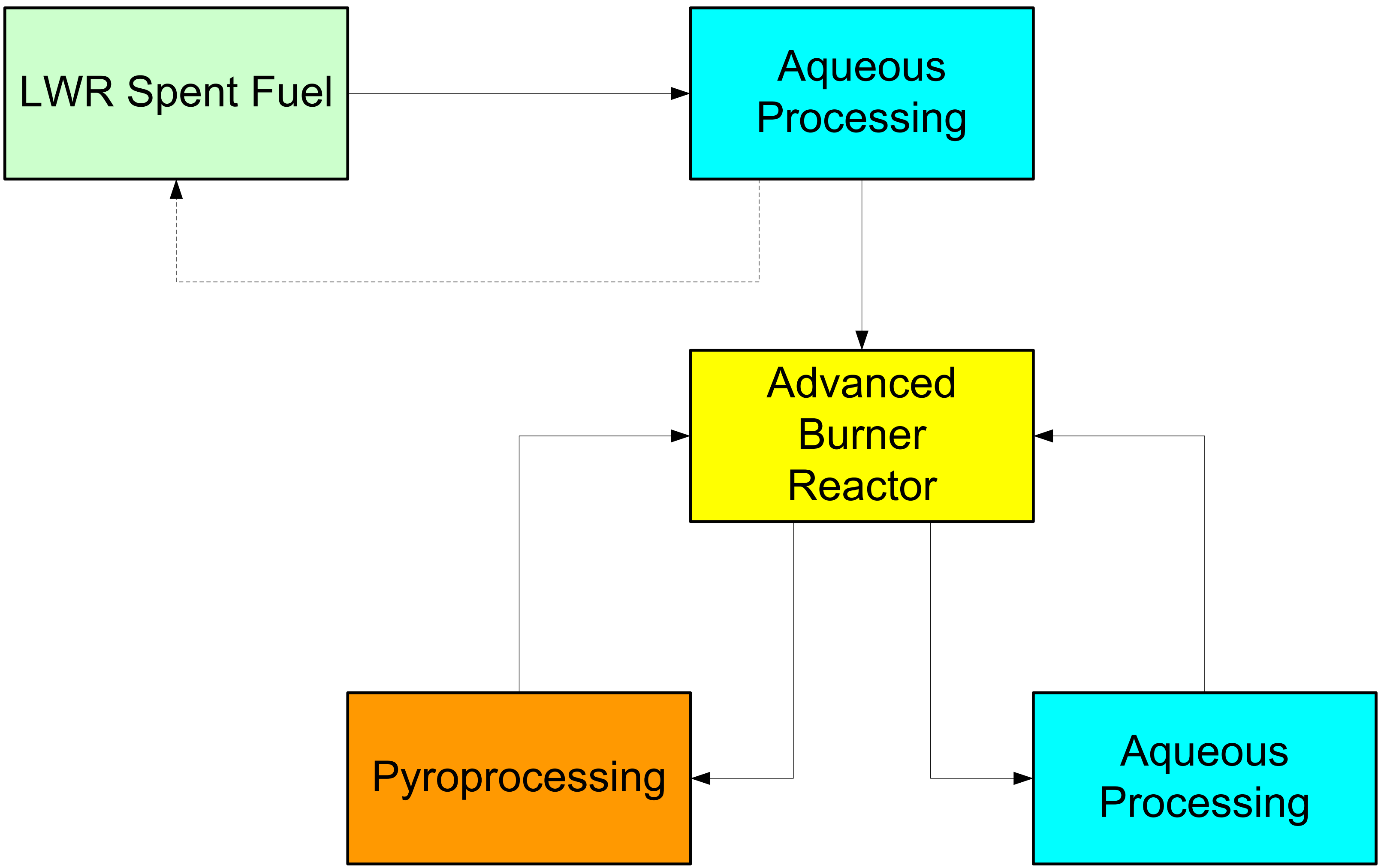
The U.S. Situation

- 103 LWRs in commercial operation for generation of electricity
- Approximately 2,000 tons of spent nuclear fuel generated each year
- U.S. utilities have now accumulated about 52,000 tons of spent fuel; awaiting disposal in the Yucca Mountain geologic repository, which will be over-subscribed by 2015
- Want to avoid the need for a second repository

Projected Spent Fuel Accumulation without Recycling



U.S. GNEP Spent Fuel Processing Scheme



Requirements for LWR Spent Fuel Processing

- Ability to accommodate very high throughputs (>2,000 t/y) economically
- Ability to achieve very high decontamination of the actinide products from lanthanide fission products
- No separated plutonium stream
- Flexibility to adapt to thermal reactor recycle of mixed oxide fuel if required

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- Led to choice of an aqueous solvent extraction process as the reference process
  - Suite of UREX+ processes

Suite of UREX+ Processes

Process	Prod #1	Prod #2	Prod #3	Prod #4	Prod #5	Prod #6	Prod #7
UREX+1	U	Tc	Cs/Sr	TRU+Ln	FP		
UREX+1a	U	Tc	Cs/Sr	TRU	All FP		
UREX+2	U	Tc	Cs/Sr	Pu+Np	Am+Cm+Ln	FP	
UREX+3	U	Tc	Cs/Sr	Pu+Np	Am+Cm	All FP	
UREX+4	U	Tc	Cs/Sr	Pu+Np	Am	Cm	All FP

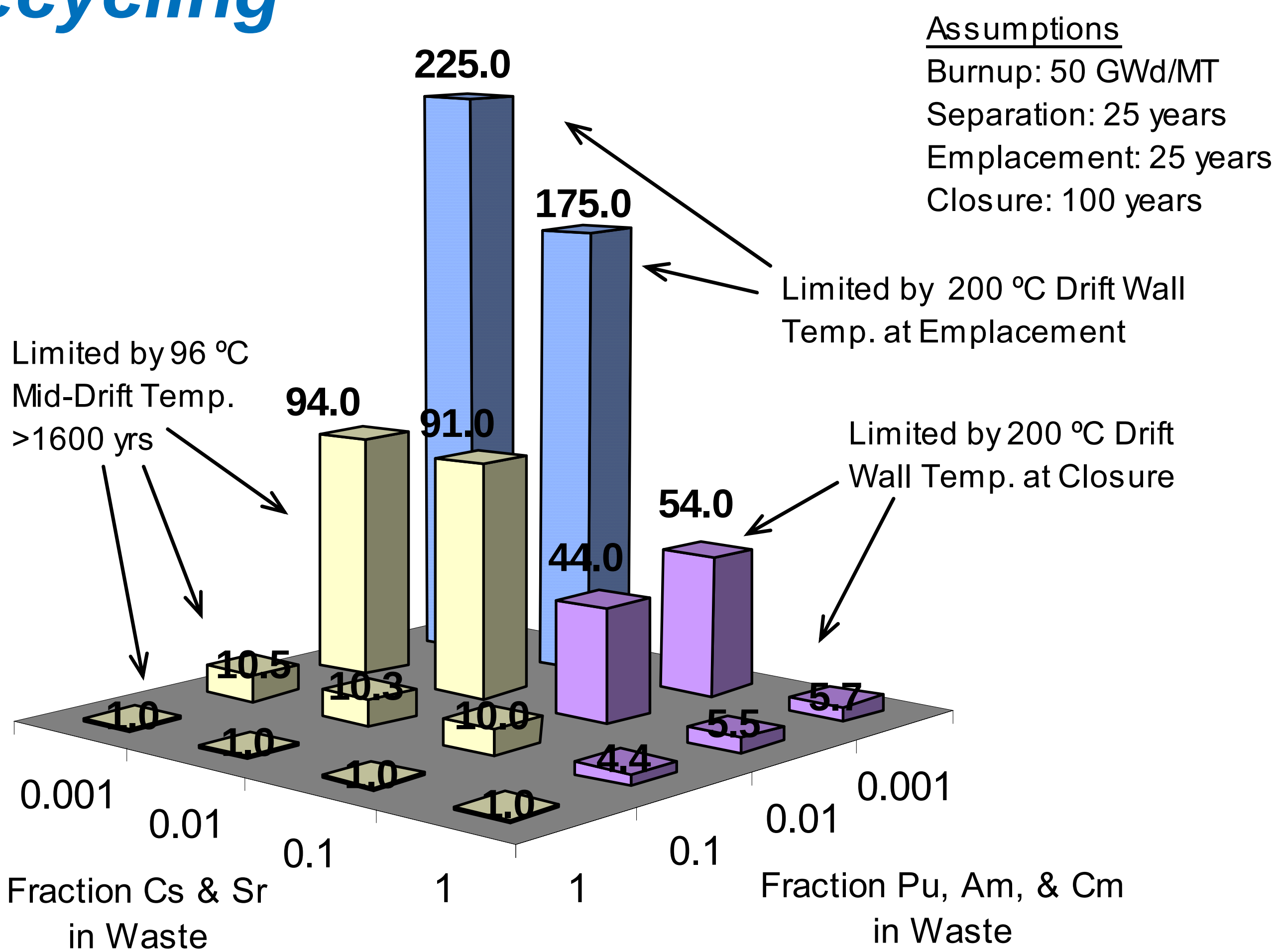
Notes: (1) in all cases, iodine is removed as an off-gas from the dissolution process.
(2) processes are designed for the generation of no liquid high-level wastes

U: uranium (removed in order to reduce the mass and volume of high-level waste)
Tc: technetium (long-lived fission product, prime contributor to long-term dose at Yucca Mountain)
Cs/Sr: cesium and strontium (primary short-term heat generators; repository impact)
TRU: transuranic elements (Pu: plutonium, Np: neptunium, Am: americium, Cm: curium)
Ln: lanthanide (rare earth) fission products
FP: fission products other than cesium, strontium, technetium, iodine, and the lanthanides

Projected LWR Spent Fuel Processing Criteria

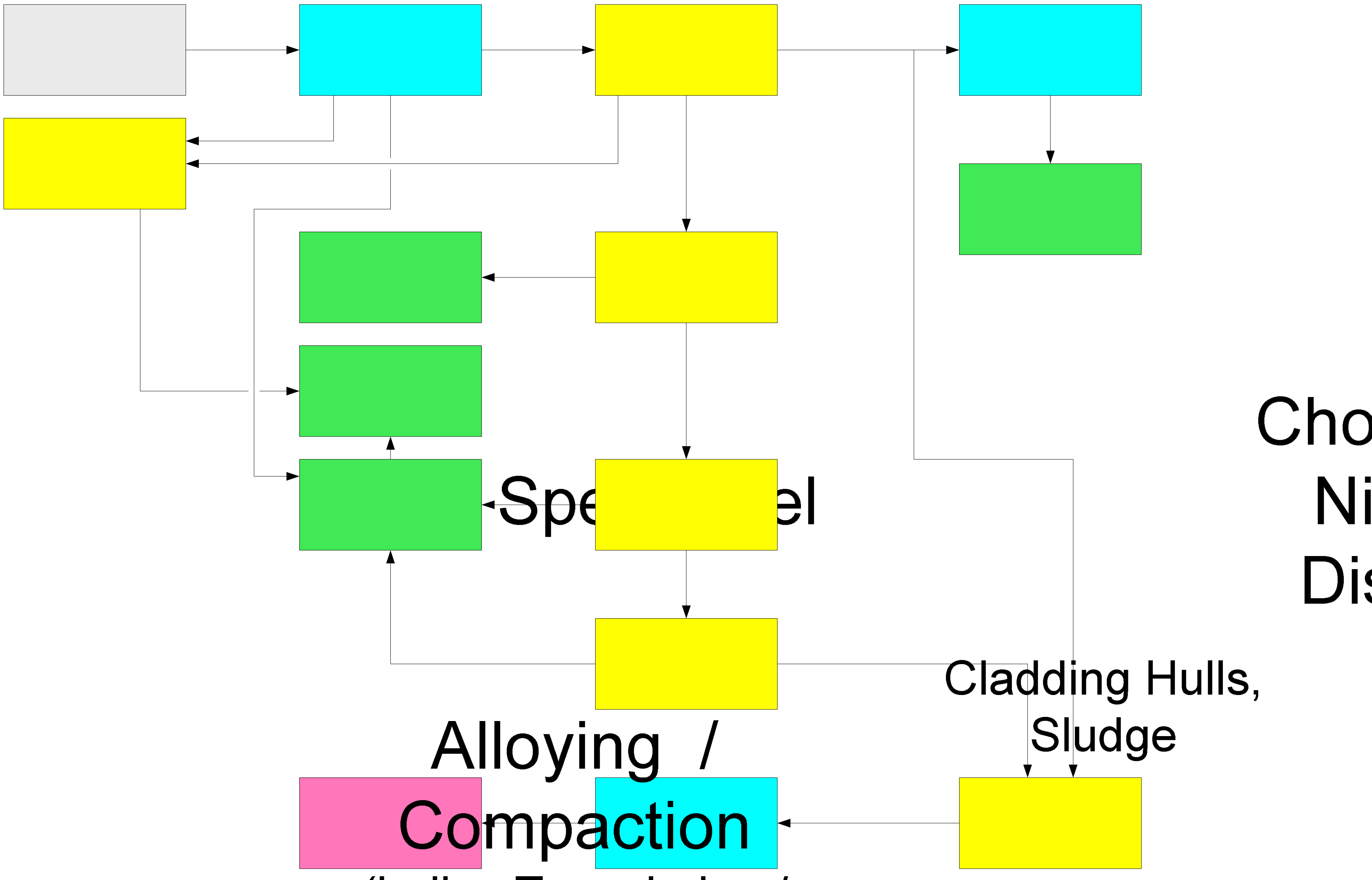
- Generation of no high-level liquid wastes requiring extended underground tank storage
- "Limited emissions" goal
  - Recovery of I, Kr, ^{3}H, $^{14}CO_2$
- Added fuel cycle costs to amount to no more than 10% increase in the busbar cost of electricity
- Efficient removal and immobilization of long-lived fission products (specifically iodine and technetium)
- Ten-fold or greater reduction in high-level waste volume relative to direct disposal of spent fuel
- ≥99.9% removal of transuranics and short-lived fission products (Cs, Sr)

Relative Increase in Repository Capacity by Recycling



Reference: R. A. Wigeland et al., Nuclear Technology, 154 (April 2006), pp 95-106.

UREX+1a Process



Tc Metal Product from Pyrolysis in Wet Argon

Laboratory-Scale Testing of the UREX+1a Process

(July 2006, 1 kg LWR spent fuel; Cooper [BWR, 34 GWd/t] and H.B. Robinson [PWR, 76 GWd/t])

Element	*Recovery Eff.*	*Remarks*
Uranium	99.9992%	Non-TRU (<100 nCi/g)
Technetium	98.3%	Soluble Tc
Cesium	>99.2%	
Strontium	>99.9%	
Plutonium	>99.99%	Total lanthanide content of transuranics <0.05% (DF>2,000)
Neptunium	>99.99%	
Americium	>99.99%	
Curium	>99.999%	

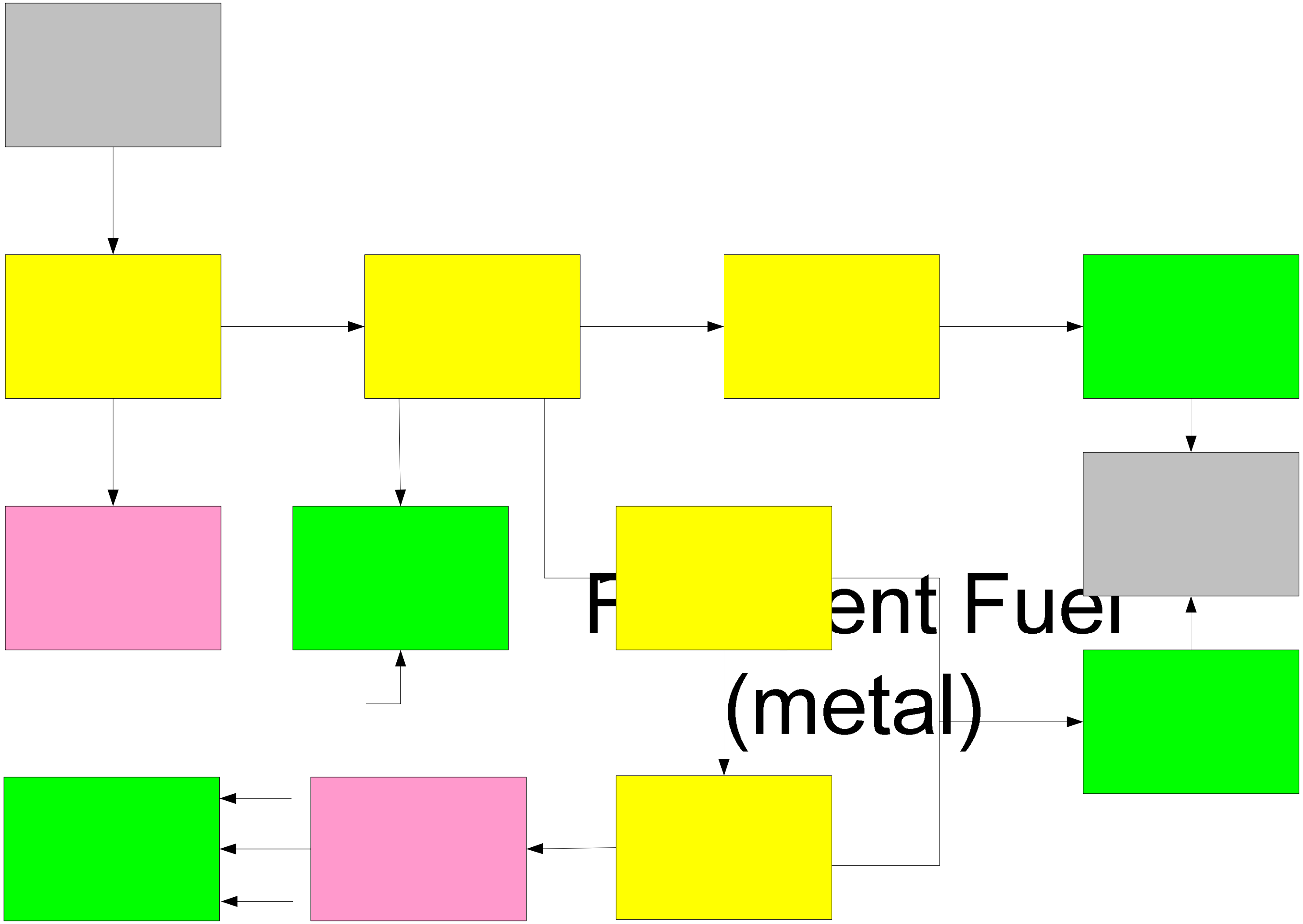
Pyroprocess Applications

- Reduction of UREX+1a oxide product to metal using an electrochemical reduction process (for transuranic recycle as metallic ABR fuel)

- Electrochemical processing of metallic ABR spent fuel for recovery and recycle of transuranics

- Processing of oxide ABR spent fuel
  - Alternative to aqueous process
  - May require aqueous polishing step to reduce lanthanide content of product

Pyrochemical Processing of FR Spent Fuel



Future Directions of the U.S. Program

- Construction and operation of the Consolidated Fuel Treatment Center (CFTC) by 2020
  - 500 – 2,500 tons per year
- Decision by the Secretary of Energy on proceeding in June 2008
- (Alternative) Engineering-scale demonstration of the UREX+1a process at reduced scale
- Complete development of UREX+1a process in 2009
- Continue development of pyroprocessing technology