UT-BATTELLE

Fuel Cycle Advantages Resulting from the Significant Inventory of U.S. Spent Fuel

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ABSTRACT

Given the existing inventory of U. S. spent fuel and the present rate of fuel utilization, a processing scheme and a closed fuel cycle is proposed that takes advantage of a very large inventory of old spent fuel. The main advantages are a very significant delay on the need of a second repository and specialized transmutation systems. Processing first the older fuel significantly reduces the overall cost.

Spent Fuel Processing or Second Repository ?

- The statutory capacity of Yucca Mountain (63000 MT) will be filled with commercial spent fuel generated from the inception to approximately the year 2010.
- The fuel discharged afterward will require an extension of the capacity at Yucca Mountain or the construction of a second repository.
- Any significant growth of nuclear energy production will require the construction of multiple repositories.
- An early deployment of a nuclear waste processing plant fully integrated with the repository could delay the need of a second repository into the next century.

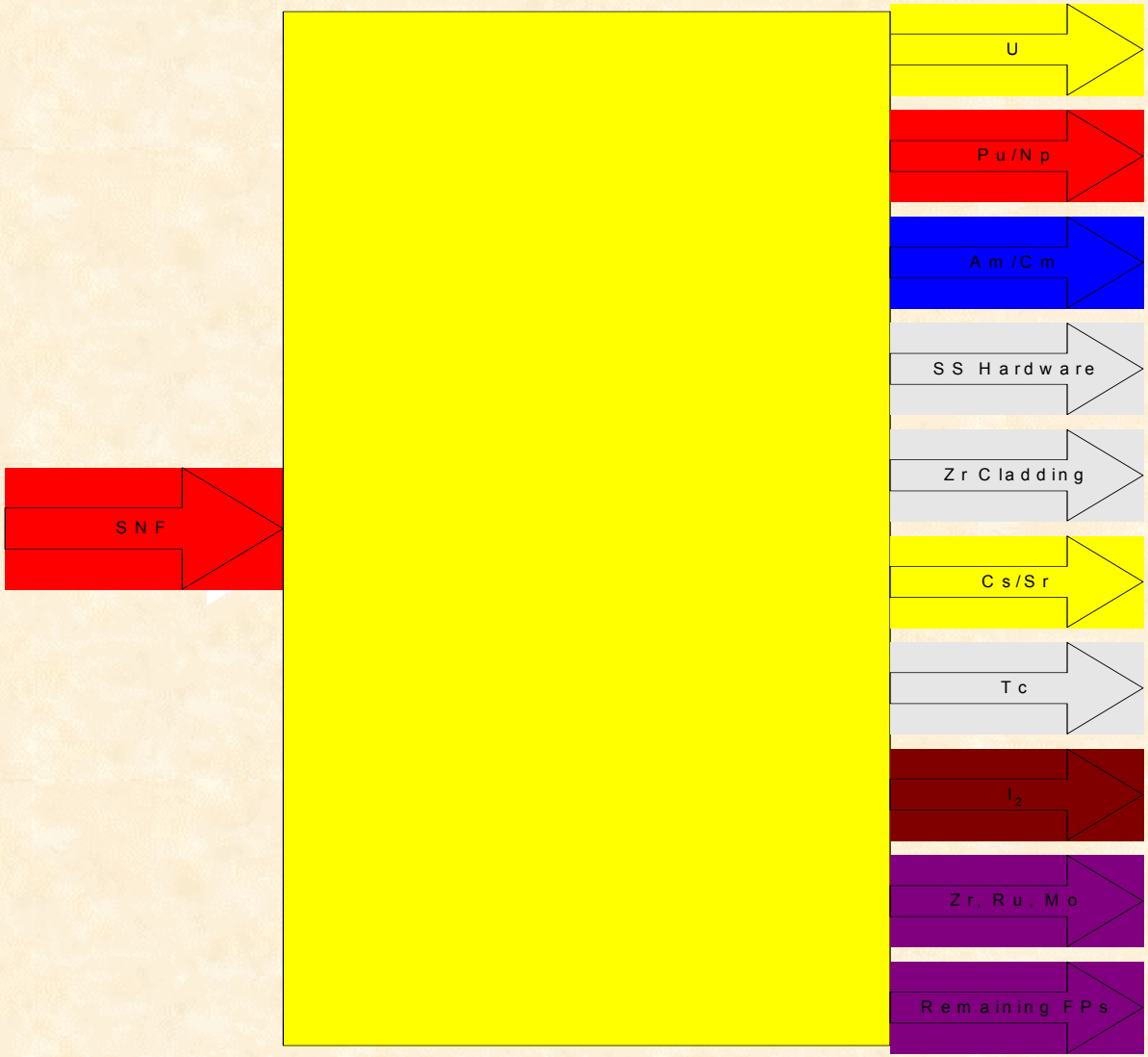
Spent Fuel Processing or Second Repository ?

- The very large cost required for the construction and operation of a repository ,
  - $42.7 billion to $57.3 billion, in 2001 dollars

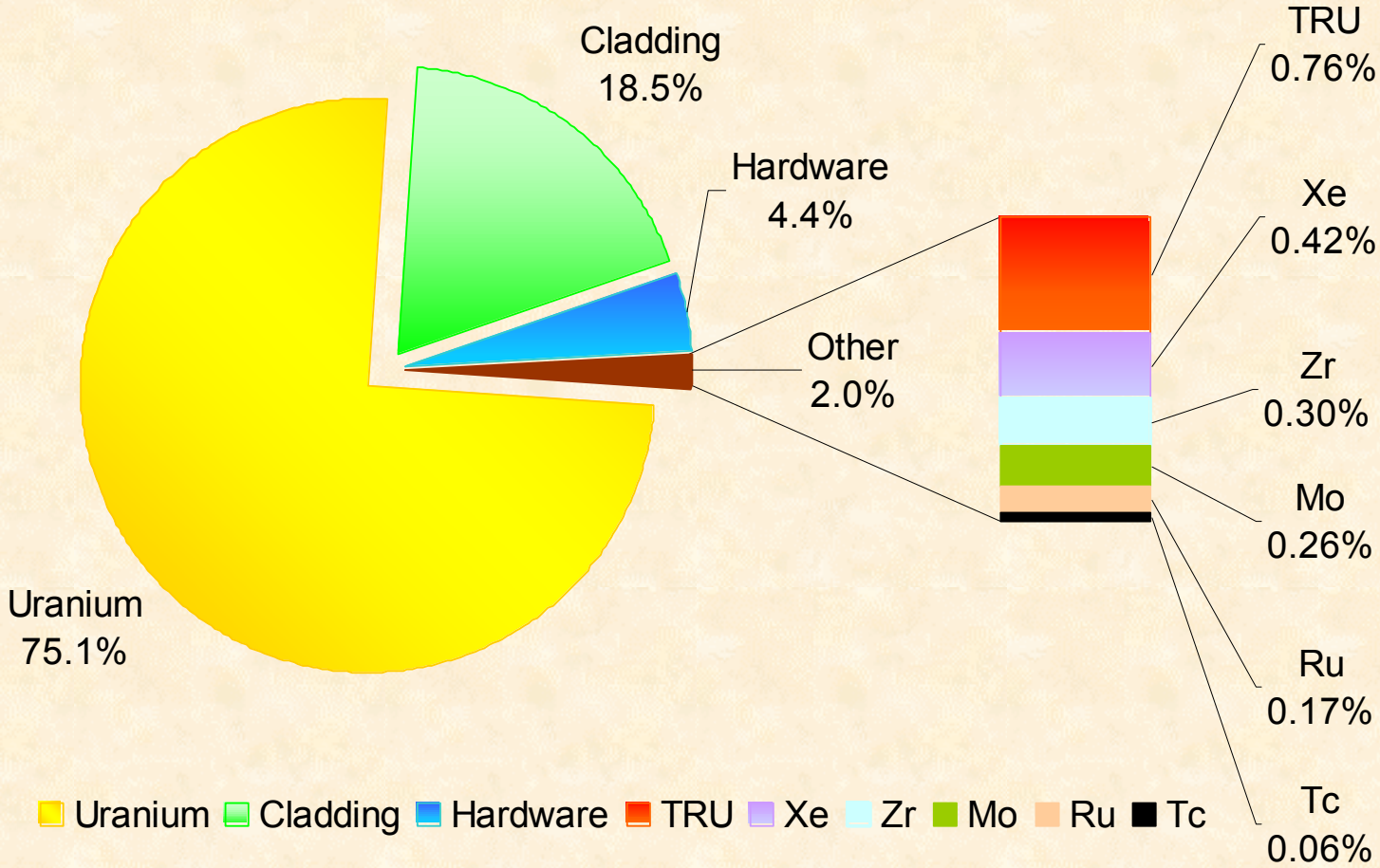
  and the very difficult problem of finding a possible location offer a significant incentive for the processing of the spent fuel to enhance the lifetime of the first repository.

- The goal is to separate different components from the spent fuel that could be reused and recycled or disposed of more economically, thus leaving a much smaller fraction to be sent to the geological repository.

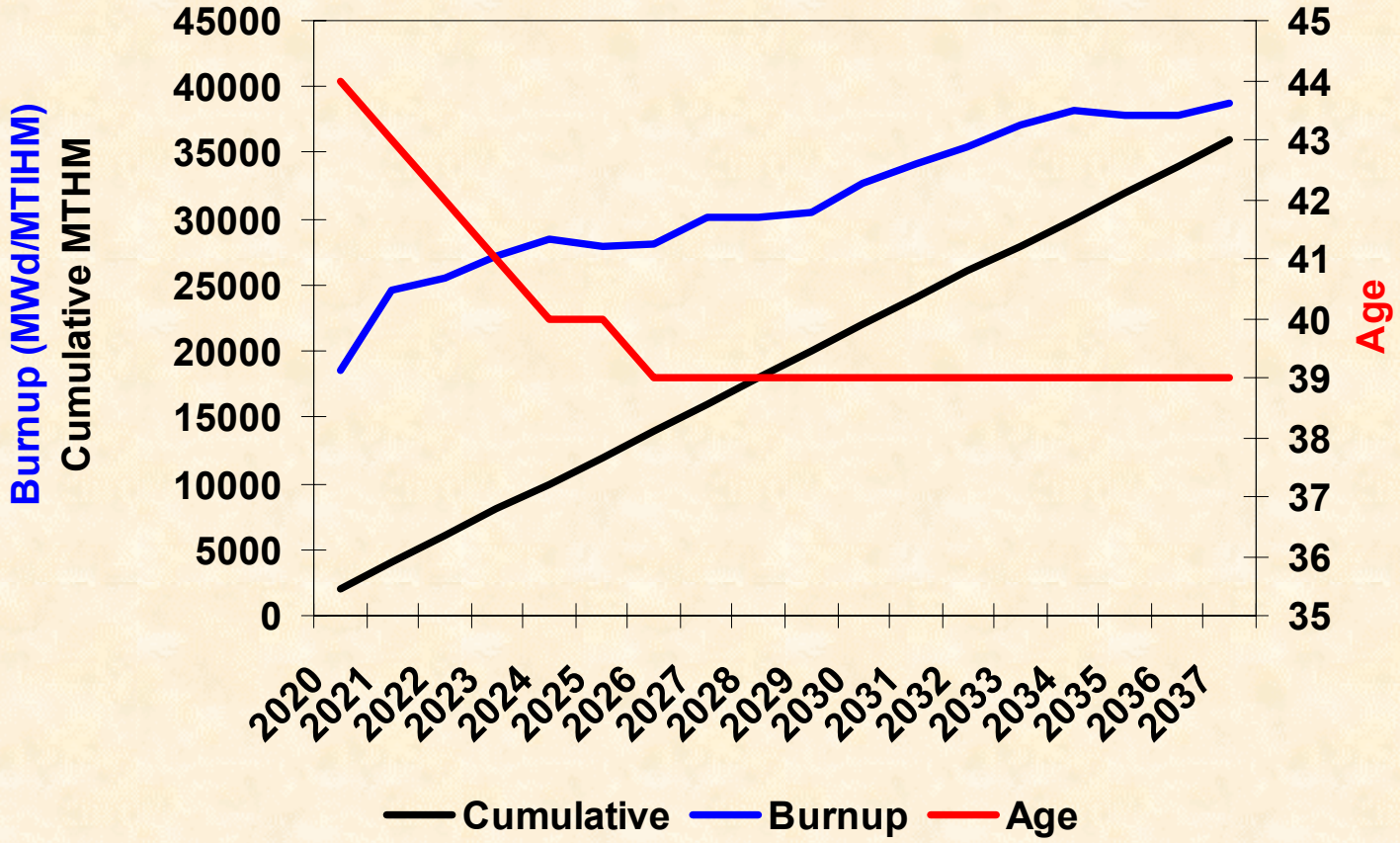
Main Components in LWR Spent Fuel



An advanced nuclear waste processing plant based on proven industrial scale technology with added features can recover and recycle more than 95% of the spent fuel.



A 2000 MTIHM plant starting in 2020, on an oldest-first basis, would never process fuel that had been cooled less that 39 years.



Relative Indicators for Spent fuel at Different Cooling Times

Item	Values relative to a cooling period of 30 years					
	150 d	5y	10y	20y	30y	40y
Activity from fuel elements	32.6	2.54	1.81	1.31	1.00	0.77
Activity from cladding	55.3	5.03	3.49	1.81	1.00	0.57
Activity of fission products	31.7	2.65	1.74	1.12	1.00	0.93
Heat from fuel elements	18.1	2.45	1.59	1.21	1.00	0.84
Amount of ^{3}H	5.26	4.07	3.07	1.75	1.00	0.57
Amount of ^{85}Kr	6.77	5.04	3.65	1.91	1.00	0.52
Amount of Cs and Sr	6.24	2.55	1.74	1.27	1.00	0.79

[a] Based on ratios to a PWR fuel at a nominal burn-up of 33000 MWd/MTIHM.

Relative Capital Costs per Module for a 1500-MTHM/Year Plant

Module function	Capital Costs (%)
Receiving	7.42
Mechanical Feed Prep	12.39
Tritium Confinement	3.47
Dissolution	7.77
Feed Prep	0.66
Dissolver off-gas	3.97
Vessel off-gas	1.16
Solvent ext, U	1.32
Solvent ext, Pu	1.48
Solvent treatment	0.99
Acid and Waste Recovery	1.82
HLW concentration	0.99
ILW concentration	1.32
LEU purification	0.66

Module function	Capital Costs (%)
LEU conversion	3.80
Fissile conversion	2.15
Head-end off-gas	0.33
HLW solution storage	2.98
HLW solidification	4.63
Fissile product storage	0.33
Cladding storage	9.91
Fuel storage	11.42
Kr storage	4.76
Cs&Sr Solidification&storage	9.52
Tc solidification&storage	1.90
Iodine solidification&storage	2.85
Total	100.00

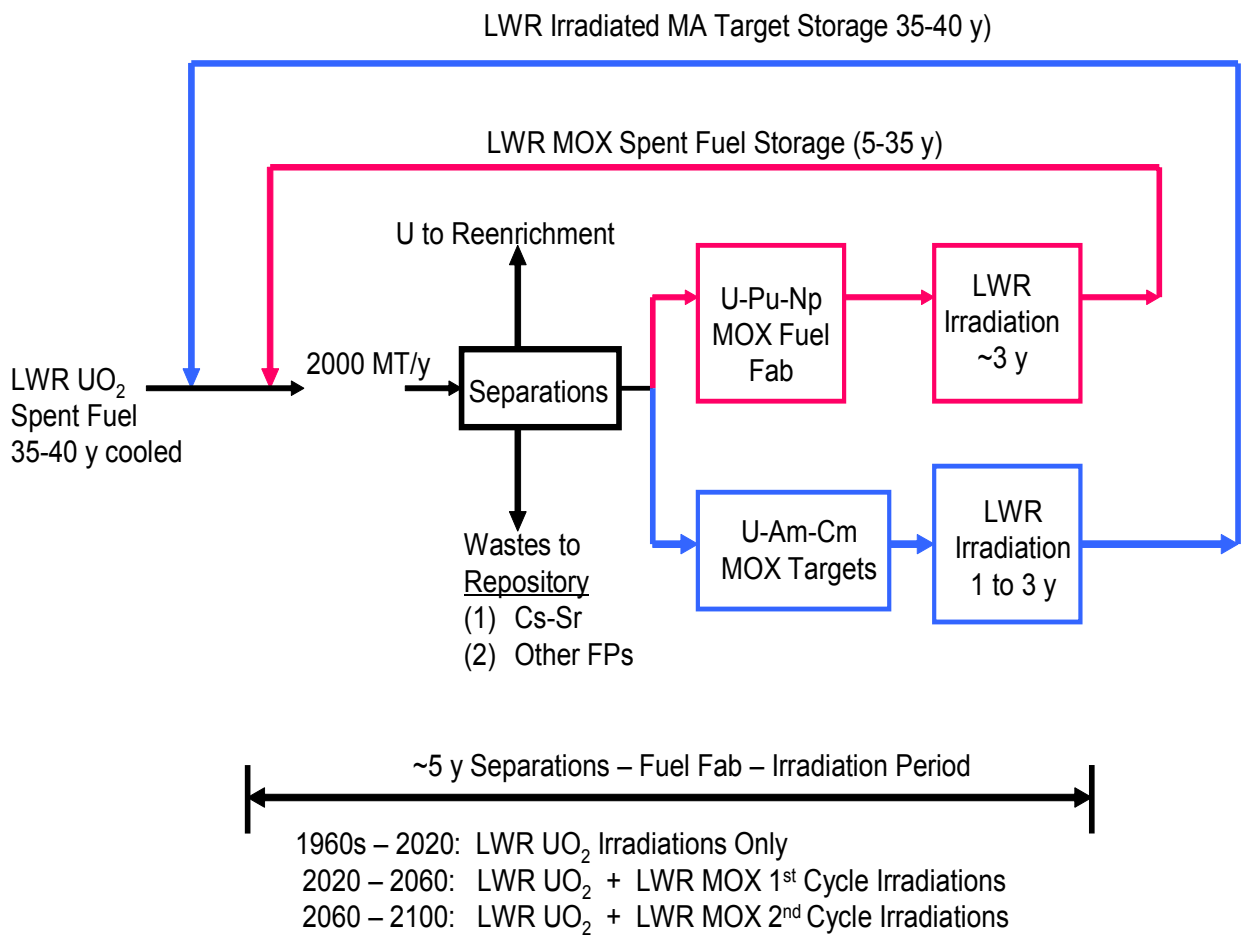
Relative Annual Operating Cost Estimates (5% of initial equipment per year)

Operating costs	%	
Labor	18.0	
Consumables	3.0	
Utilities	5.0	
Equipment replacement	4.0	
Waste treatment, disposal and storage	56.0	
HLW		15.0
Cladding		10.0
Reprocessed U		6.0
Cs/Sr		8.0
Tc		3.0
I		3.0
Kr		5.0
Fissile storage		6.0
Miscellaneous	14.0	
Total	100.0	

Proposed Fuel Cycle: ~40 years between successive reprocessing cycles

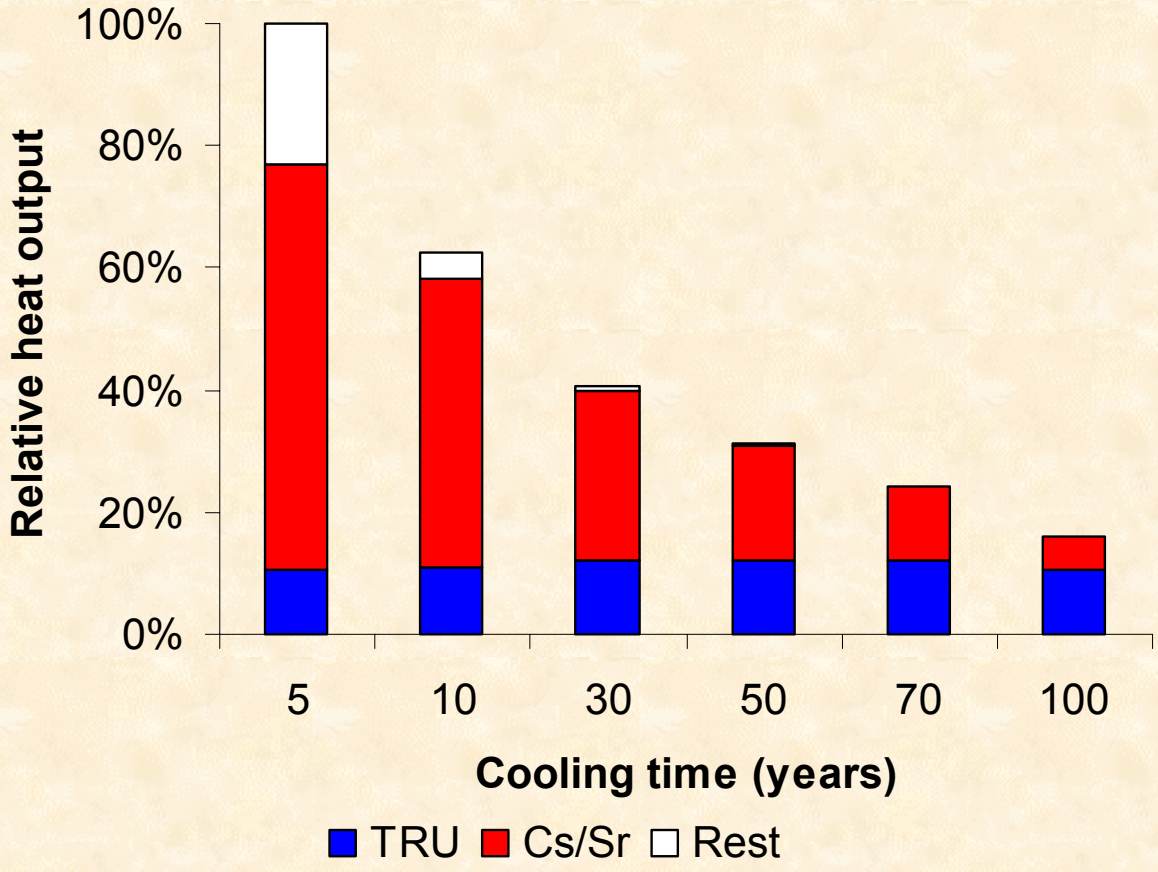
During prolonged cooling, there is a significant decay of fission products and heavy actinides.

Recent calculations showed that Am and Cm can be effectively burned in the present fleet of LWR's; significantly delaying the need for specialized transmutation systems.

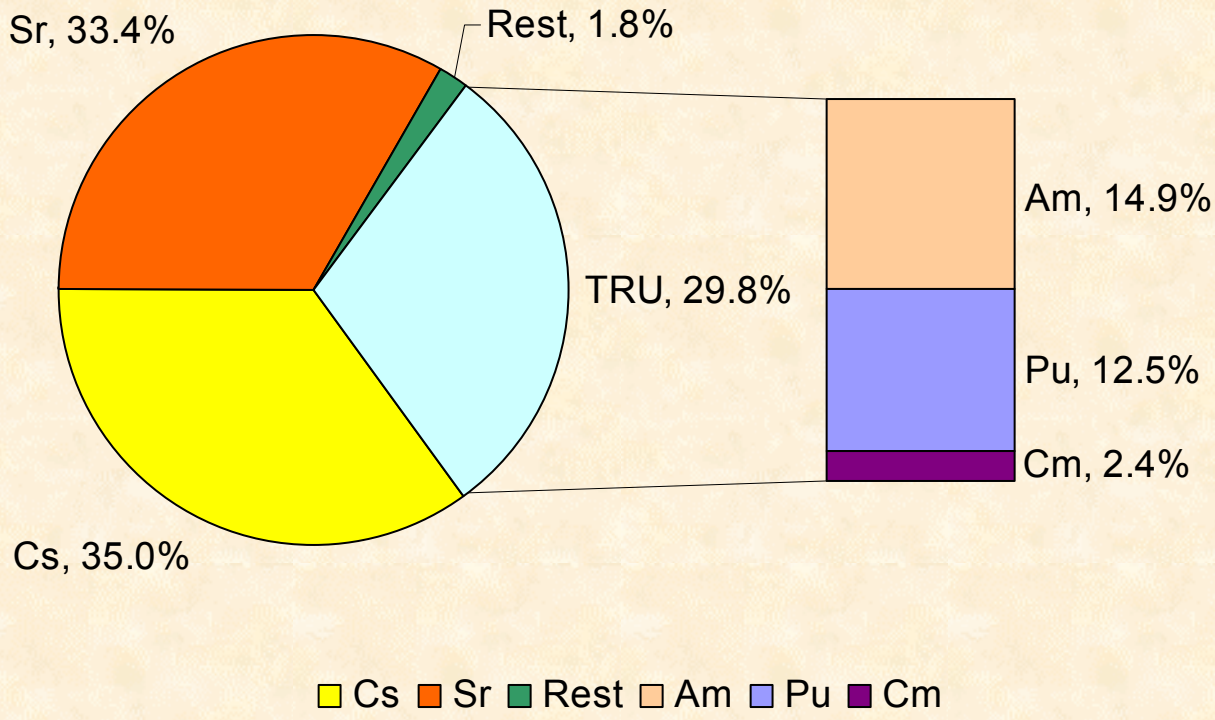


Removing heat from the waste can result in a more compact and efficient utilization of the repository.

The heat from TRU is approximately constant and predominates at long cooling times. Cs/Sr dominates during the first 50 years.



Relative heat generation of the different fractions in spent fuel stored 30 years



Summary

- The relative cost analysis shows the potential for significant savings in both capital and operational costs on the entire fuel cycle by using a strategy that enhances the cooling time of the spent fuel being processed and that conforms to the present reality.
- Other qualitative advantages of the older fuel first are:
  - much lower heat load to the repository for a given separations efficiency, i.e. less stringent separation efficiencies for Cs and Sr
  - significantly lower growth of very heavy actinides from cycle to cycle,
  - very long time between fuel reprocessing cycles, only one or two cycles need to be analyzed for the foreseeable future.
  - significantly reduced quantities of Cm
  - significantly lower growth of Am because there is much less ^{241}Pu in the separated Pu.