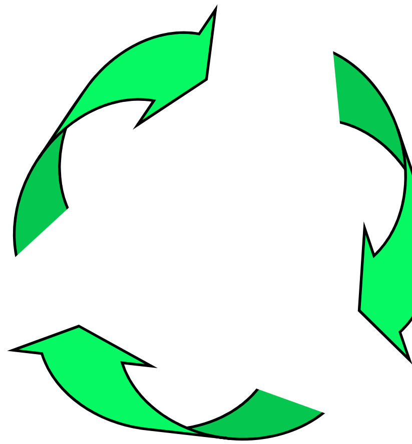
Using LFTR to Minimize Actinide Wastes

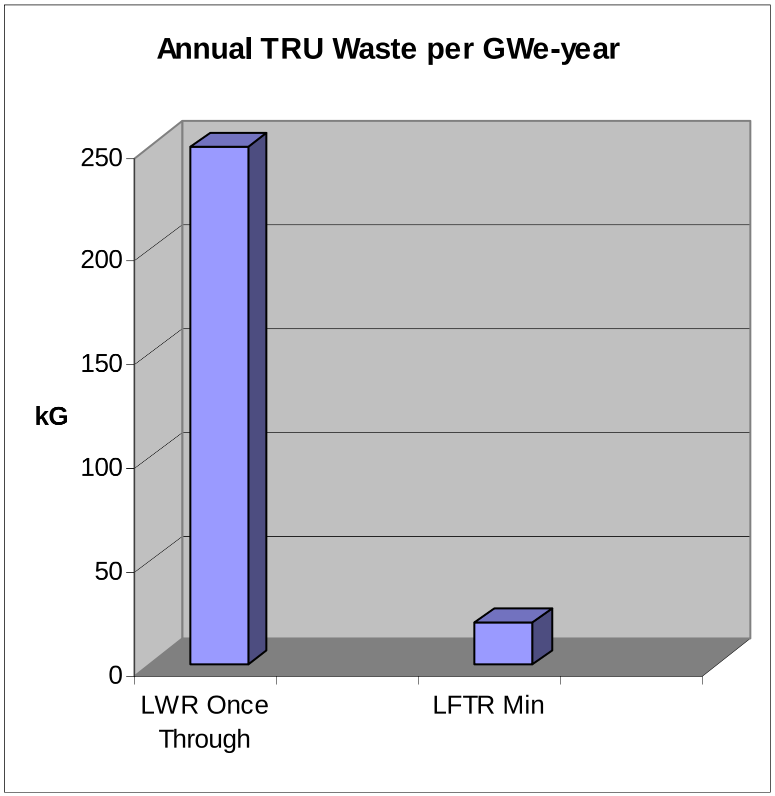
Lars Jorgensen

30 March 2010



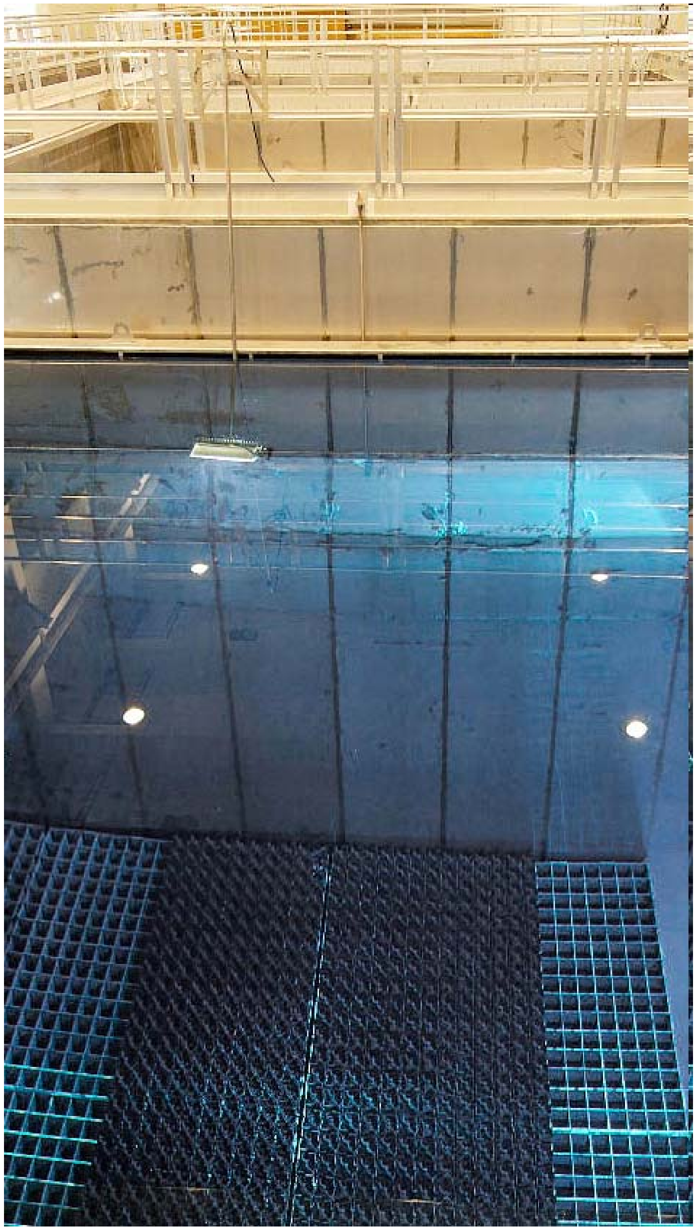
- REDUCE production of plutonium 12x
- REUSE existing LWR TRUs
- RECYCLE TRUs generated by LFTRs
- Full Cycle including the end-game

Reduce TRU Production 12x Using LFTR



If nuclear experiences a world wide expansion using LWRs the amount of TRUs generated in the future will much larger than the existing stockpiles.

First priority should be to reduce the quantity of TRUs being produced. Starting from 232Th allows a 12x reduction in the production of TRUs



Reuse Existing TRUs from LWRs to Start LFTRs

Recycle TRUs from LFTRs

- Much smaller source (20kg/GWe-yr)
- Depending on processing it is either 237Np or 238Pu (quite different than LWRs).
- Extraction technology not settled
  - Fluorination (Np easy, Pu hard, Am/Cm not likely)
    - Ornl achieved 99.75% for U in a single 44" fluorinator
    - Ornl achieved 0.01 mg/g for Pu which would be 99.73% for our concentrations (four passes through 52" fluorinator)
  - Liquid metal exchange (ORNL plans, Grenoble and Dr. LeBlanc's plans).
    - Grenoble group estimates 99.999% for U, 99.99 for Pu, and 99.9% for Am/Cm (combined results for fluorination and LME).
    - Experimental results I've found so far have had disappointing throughputs
  - Electrorefining (IFR's plan)
    - Estimated at 99.9%

Can't Ignore U233, U234

- Th/U cycle produces some U232, U233, U234 actinides
- They are roughly comparable to the equivalent nuclides in the U/Pu cycle

Nuclide	Half-life	Alphas	Nuclide	Half-life	Alphas
U232	70	6	Pu238	88	1 then u234
U233	159,000	6	Pu239	24,000	1
U234	245,000	7	Pu240	6,563	1

Fortunately, it is at least 10 times easier to extract uranium than plutonium.

Inventory at Shutdown

- With full recycling each GWe worth of reactor will contain 2 to 6 tonnes of problem actinides (excludes u235, u236, u238).
- Shutdown inventory roughly matches LFTR min leakage over 200 years. It exceeds LFTR best by 100,000x.
- “Consequently, the radiotoxicity is dominated by the actinide inventory. This consideration holds for all GEN-IV reactors: long lived nuclie stored in the core, are not considered as wastes, but as soon as the reactor is no longer in operation, there is a huge amount of long lived wastes.”

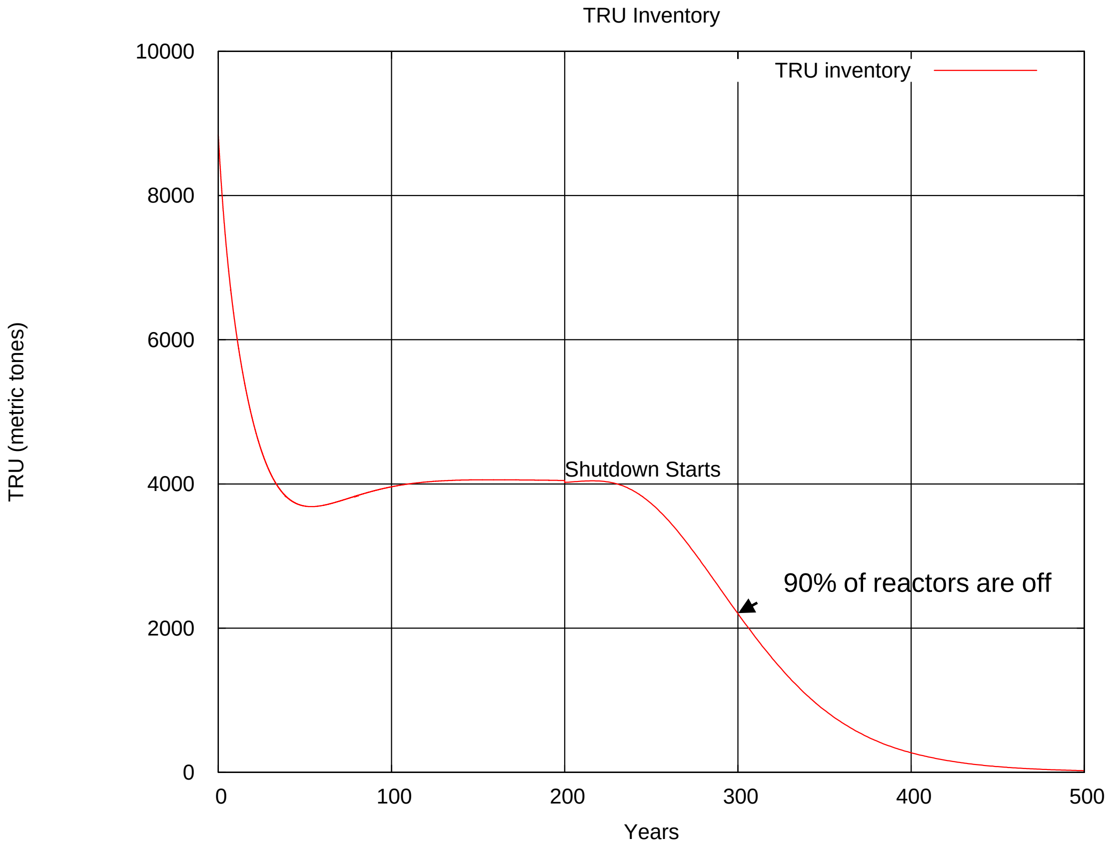
- => We need a game plan to eliminate the inventory as we shut down the reactors.

End Game

- Suppose we have 9,000 GWe total LFTR nuclear power
- Shutdown 10% and transfer the core actinides to the remaining reactors.
- The core actinides is 80-85% thorium, remainder is 95% uranium.
- Use the shutdown actinides as fuel in place of pure thorium in the same reactors.
- Reactivity will be slightly high initially so we can transmute Xe or 129I.
- When fuel from shutdown reactors has been consumed repeat the process.
- Eventually, fuel quality will degrade as even isotopes build up. Run for a few years on thorium feed to restore fuel quality.

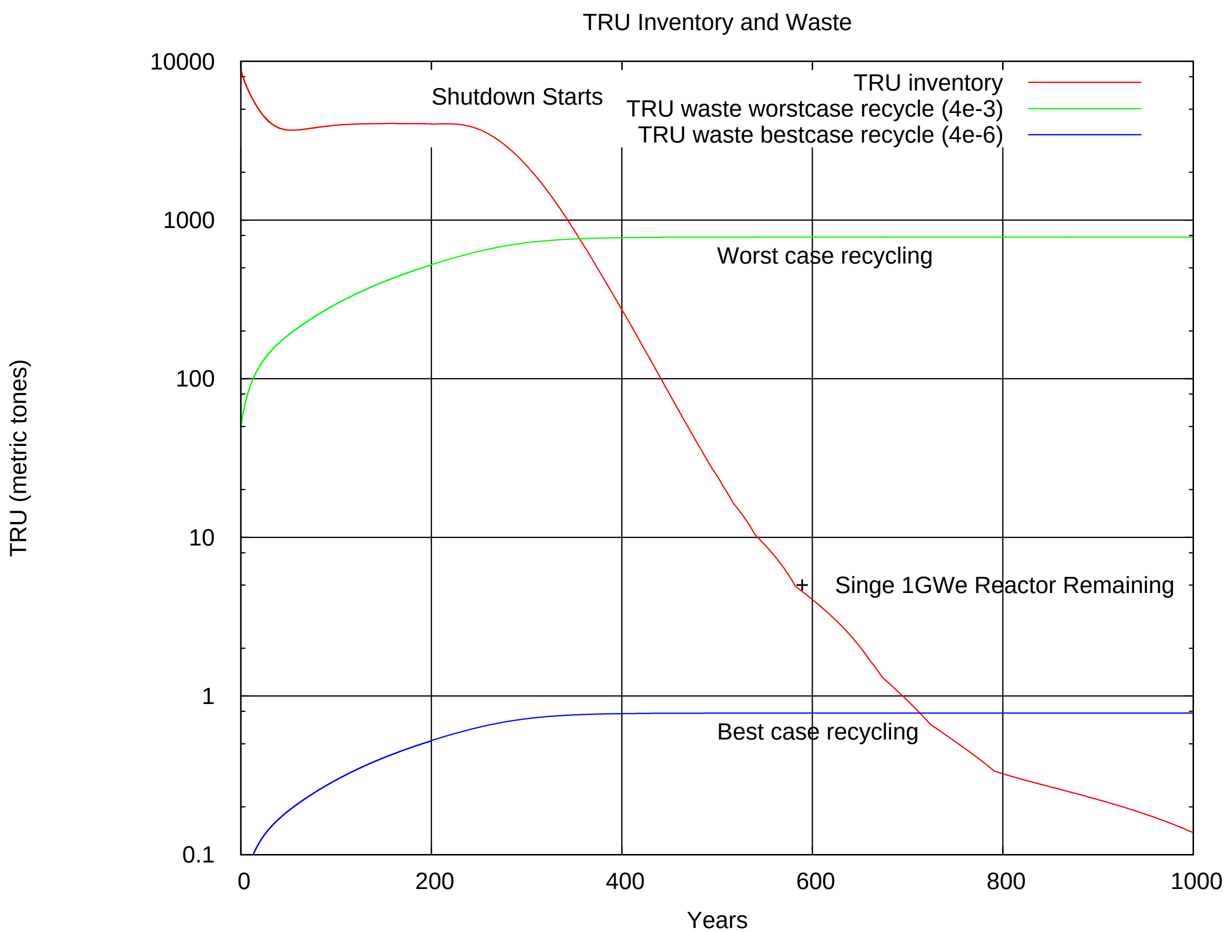
TRU Inventory

- Use LWR SNF/Pu to start fleet of LFTRs (9,000 GWe)
- Operate steady for 200 years
- Shutdown gracefully to eliminate inventory
- Plot TRU inventory versus time



1) We can expand nuclear power 20x and still keep the TRU inventory below current levels!
2) We need to be patient in shutting down the reactor fleet (about 90% TRUs destroyed in 200 years). Takes 50 years to shutdown 90% of the reactors
3) Effectively this changes a 24,000 year half-life to 30 years

Shutdown Inventory can be Small



With time we can reduce the inventory to arbitrarily small values.

Once below a unit reactor we can build smaller reactors to support destruction of remaining TRUs

Also shown is the cumulative actinides sent to waste through leakage

It takes 500 years of shutdown to get the shutdown inventory down to the levels of best case recycling over 200 years.

Conclusions

- We can use LFTR to destroy existing SNF TRUs, consume surplus weapons grade plutonium, provide electricity on a world scale, and have less problem actinide wastes than we currently have.
- The fuel flexibility of LFTR allows us to recycle the fuel indefinitely.
- In the end only a very modest quantity of problem actinides make it into the waste stream.

Backup Data on Pu Extraction

- Falling drop fluorination method (ORNL 4224 pg 17)
- Measured results using a 52” fluorinator
  - 2.58 mg/g -> 0.33 mg/g
  - 0.026 mg/g -> 0.01mg/g
- Equilibrium concentration for a TMSR-NM (MSFR) 4.4 mg/g
- Two passes in a 104” fluorinator should take us from 4.4 mg/g -> 0.01mg/g or 99.8%

- Calculations from the Grenoble group anticipate leakage rates of 10^-5 for U, Np, 10^-4 for Pu, and 10^-3 for Cm, and Am. (Optimizatino and simplification of the concept of non-moderated Thorium Molten Salt Reactor”, Conference on the Physics of reactors, Switzerland, Sept 14-19, 2008