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The Rationale for Reprocessing and Recycling

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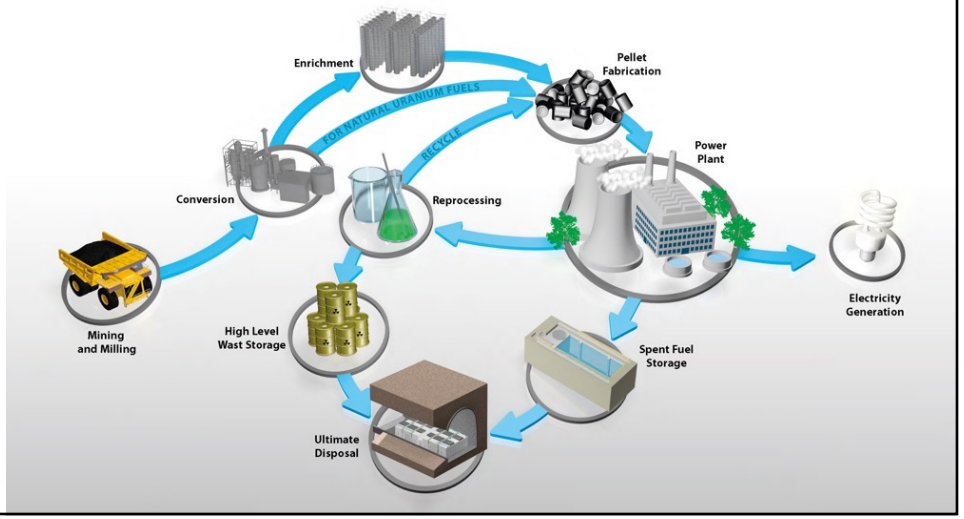
U.S. DEPARTMENT OF ENERGY

What is "Reprocessing" and "Recycling"?

- Two options exist for managing spent nuclear fuel
  1. Dispose of Spent Nuclear Fuel (SNF) after containment in a suitable waste form in a repository
     - The "Open" or "Once-through" fuel cycle
  2. Separate out the reusable components for (*potential*) recycling, and only dispose of the residual waste products
     - The "Closed" fuel cycle
- Recycling does *not* have to follow reprocessing

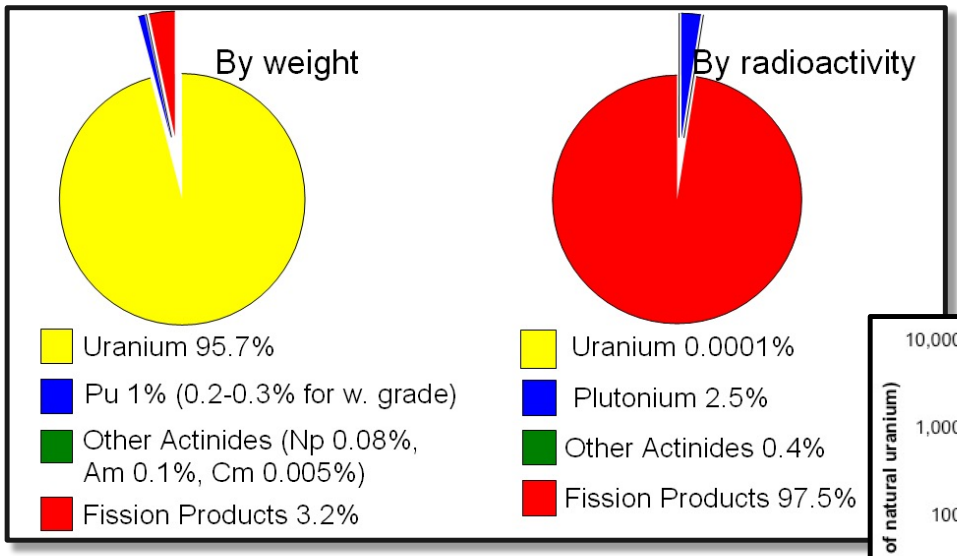


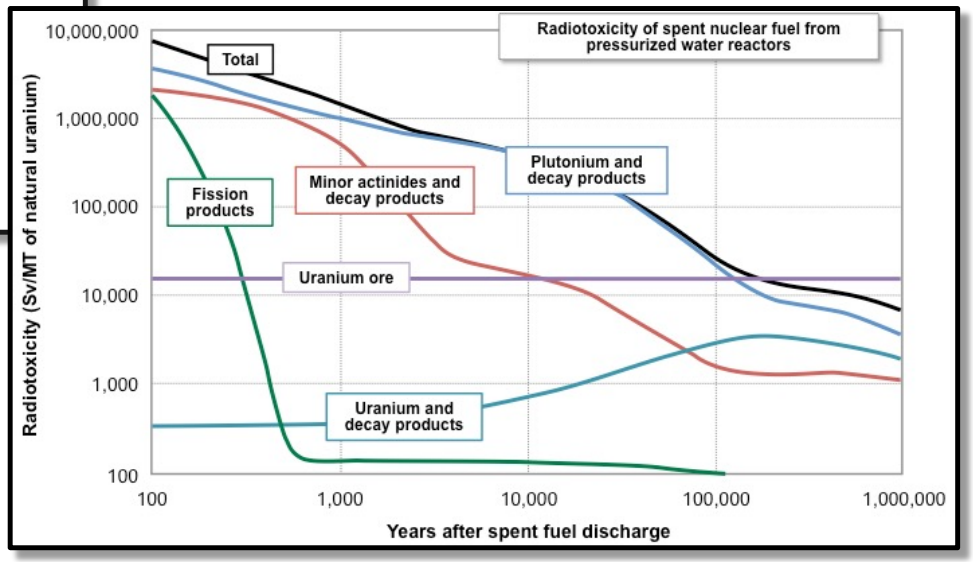
Rationale for Reprocessing and/or Recycling

- Technical needs
  - e.g., cannot indefinitely store certain SNF
- Waste management
  - Either reduced volume, or change in form
- Economics
  - Price of U, enrichment, fuel fabrication, reprocessing, storage, disposal
- Resource utilization / sustainability
- Strategic reserves

→ Analogous to "domestic trash recycling"

What Constitutes Spent Nuclear Fuel?





80,000 tHM of spent fuel results in:

~180,000 m^3 SNF for direct disposal

~ 13,000 m^3 VHLW from reprocessing

Radiological Impacts of Spent Nuclear Fuel Management Options A Comparative Study, OECD-NEA
ISBN: 9789264176577, June 2000
Radioactive Waste and Materials Inventory", July 2005, CoRWM document 1279

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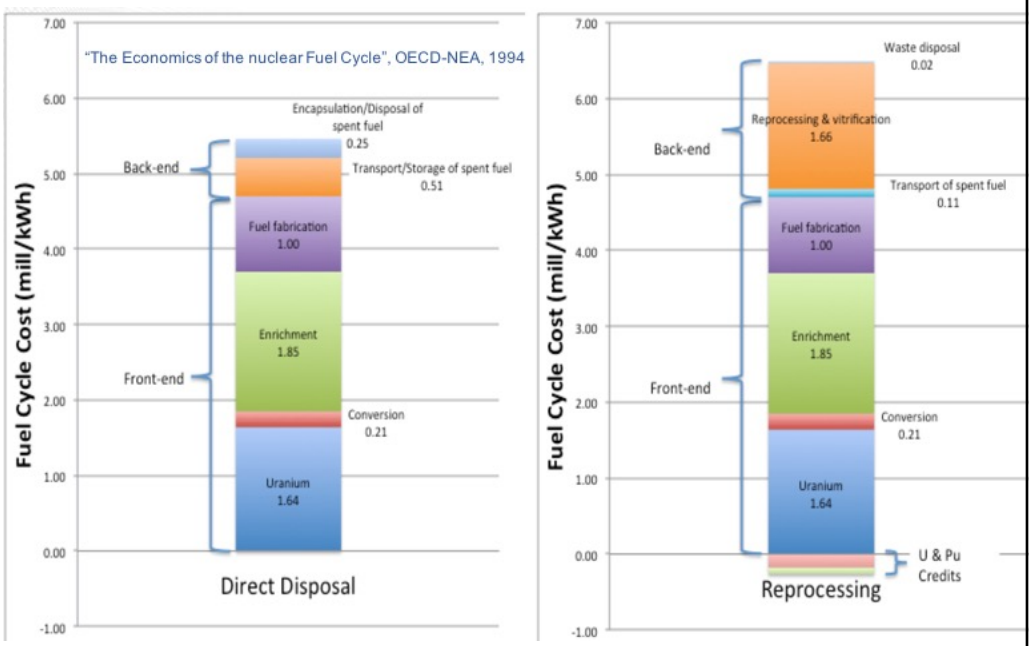
Economical? And if so, how?

- No….yes…..maybe…..it depends on:
  - Approach to economics:
    - Direct disposal costs are usually deferred a long time into future and "discounts" costs away
  - Price of U ore and enrichment
    - Makes value of Pu and U recycle higher
  - Burnup achievable in LWRs
    - Higher burnup → more ore & more SWUs for U fuel, but once reprocessed, Pu is "free issue"
  - Cost of spent fuel storage and disposal
- In general, the cost per kg HM of conditioning irradiated fuel and direct disposal is comparable to that of reprocessing
  - Depends on assumptions and market prices



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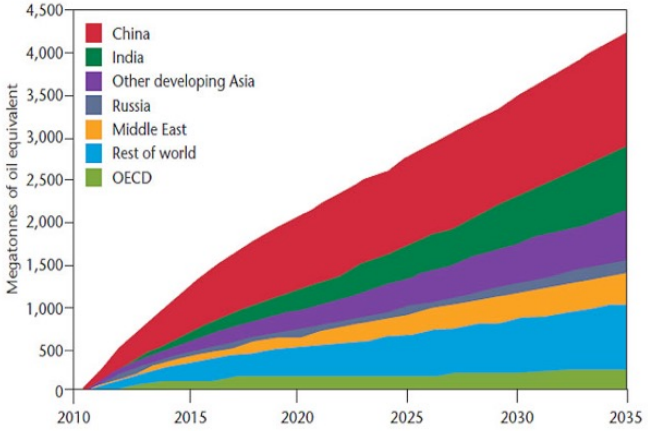
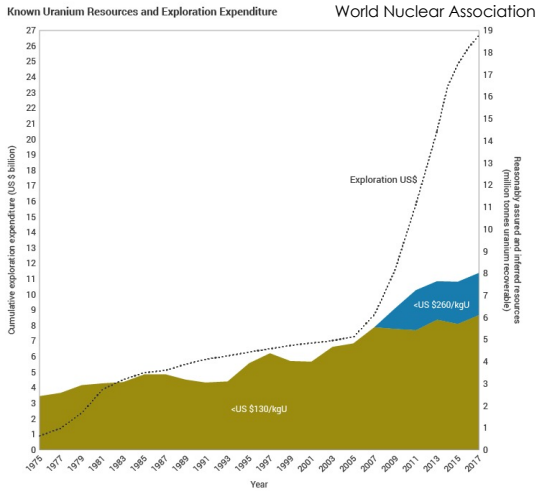
World Energy Demand is Growing…

- We may not run out of uranium ore, but at a minimum there will be greater pressure on a finite resource, driving up prices
  - Increase in China to 200 GWe will alone consume ~50% of world's economically recoverable U
- Reprocessing and recycle in LWRs can save ~20% fuel resource, but still low utilization
  - Need advanced reactors to maximize resource utilization
    - The majority of advanced reactors (non-LWRs) being proposed have some form of recycle included





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Other Factors to Consider

- Products
  - What "products" does one want and why?
    - Reactors (current or advanced) vs. waste forms for disposal
- Safeguards and non-proliferation issues
  - **All** fuel cycles regardless of reprocessing need safeguards and security
  - Not suggesting all countries should reprocess – same with enrichment
  - Has been demonstrated successfully in other countries
- Strategic Asset
  - Reprocessed U and Pu can be seen as an asset against a backdrop of risks associated with breaks in the supply chain
  - Value based on comparison with U or with energy extracted?
- Many other "metrics" too…

State Department 'Diplomacy Lab' with UT Knoxville's Bredesen Center assessed drivers for reprocessing/recycle

P Political	E Economic	S Social	T Technology	E Environmental	L Legal
• Nuclear policy • Trade policy on reprocessing • Trade with others • Stability of non-proliferation regime (perception and policy) • National vs. prefecture politics • Energy security / reliance • Military power • US – Japan relations • Relations with IAEA • Existing nuclear trade (e.g. U ore, fuel)	• Cost of capital for reprocessing and MOX fuel plants • Cost of operations and maintenance of above • Sale of reprocessing / MOX fuel • Cost of electricity to consumers • U ore cost projections • Cost of U fuel • Avoidance of imported coal, oil, gas • Avoided U ore purchase & enrichment • Job creation / losses • Reduction in repository needed • Trade • Taxation • Inflation • Additional industrial spin-offs e.g. isotope production	• Public health • Public support (nuclear & reprocessing) • Availability of skilled workforce • Jobs • Acceptability of proliferation risk • Military power perspective • Energy security • Economic growth • Technological advancements	• Challenges to build, operate, and regulate reprocessing and MOX facilities • Fuel cycle stages (additional or removed) • Additional industry spin-offs • Military power • U/Pu co-extraction vs. PUREX • Technology R&D for reprocessing, MOX, licensing etc • Security enhancements • Security to counter non-proliferation (Japan, IAEA) • Safety	• Repository size, performance etc • Climate change / emissions • Emergency response plan • Discharges from reprocessing & MOX plants • Waste production / avoidance (inc. spent fuel) • Transportation of wastes (created or avoided) • Public & worker health • Avoidance of U mining • Use of nuclear vs. alternative imports	• Public health • Regulations • Land use • Non-proliferation • Licensing • Contracts (import / export control) • Safeguards commitments

Challenges Remain…

Recognition & Acceptance:

- There are potential economic, waste management, sustainability, and energy independence benefits to closing the fuel cycle
- Requires longer-term perspective by governments and investors
- Many of the technologies have been demonstrated, and can be part of a solution, but only if the conditions are right
- Does not remove the need for a repository

Regulation:

- There are regulatory challenges to moving to any new technology
- For closing the fuel cycle, this means fuel cycle and reactor facilities
- Includes international and domestic regulators; safety, safeguards, security
- Technical expertise and experience needs to maintained and developed

***Public Opinion*:**

- Not just an issue for 'closing the fuel cycle'
- Waste management, economics, and safety top issues for the public
  - Closing the fuel cycle has the potential to address each of these
  - "Intergenerational equity" needs to be addressed

Food for Thought…

"Recycle the present, save the future"
Anonymous

"Societies only have waste products while acquiring fresh raw material remains a cheaper option than recycling"
Peter F. Hamilton, The Naked God

"We live in a disposable society. It's easier to throw things out than to fix them. We even give it a name - we call it recycling"
Neil LaBute

"I only feel angry when I see waste. When I see people throwing away things we could use."
Mother Teresa

"If you want grown-ups to recycle, just tell their kids the importance of recycling, and they'll be all over it"
Bill Nye