Report to NEAC of the Fuel Cycle Subcommittee on its Meeting of 11/1-2/2012

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Washington DC

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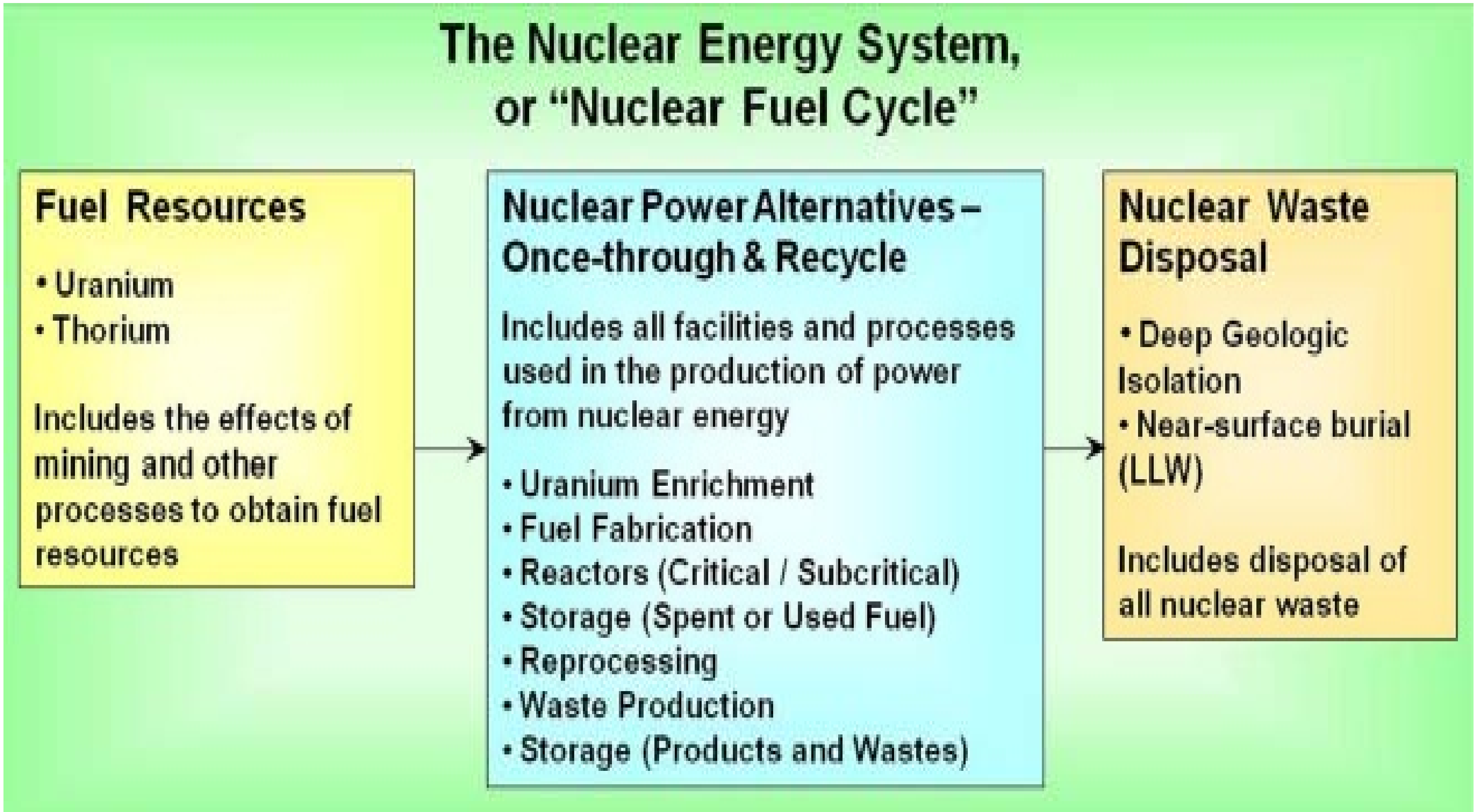
Fuel Cycle Options Study

- Objective – Narrow the Options for Future Systems to a few that are Affordable
- Create an Analytical Framework That Allows All Alternatives (over 5000) to be Evaluated Objectively Against a set of Criteria
- Methodology
  - Group Options with Similar Characteristics (once through, single recycle, multi-recycle
  - Identify Representative Option from Each Group (38)
  - Develop Criteria (9) and Metrics (24)
  - Evaluate and Rank Options

Fuel Cycle Options



Summary of Criteria (9) and Evaluation Metrics (24) to Evaluate options

- **Nuclear Waste Management** (5)
  - Relative Mass of SNF + HLW disposed per energy generated
  - Relative Activity of SNF + HLW (10E2 years) per energy generated
  - Relative Activity of SNF + HLW (10E5 years) per energy generated
  - Relative Mass of DU/RU disposed per energy generated
  - Relative Volume of LLW per energy generated
- **Proliferation Risk** (3)
  - Maximum FOM_1 (nominal fuel cycle material)
  - Maximum FOM_1 (material with misuse technology included in the fuel cycle)
  - Maximum FOM_1 (material with clandestine use of any technology)
- **Nuclear Material Security** (1)
  - Maximum FOM_1 (nominal fuel cycle material)
- **Safety** (1)
  - Relative Safety Management Challenge
- **Financial Risk and Economics** (1)
  - Levelized Cost of Electricity at Equilibrium
- **Environmental Impact** (5)
  - Land Use per unit of energy production
  - Water Use per unit of energy production
  - Radiological impact - total estimated worker dose per unit of energy production
  - Chemical impact - chemical hazard index per unit of energy production
  - Carbon impact - CO_2 released per unit of energy production
- **Resource Utilization** (2)
  - Natural Uranium required per unit of energy production
  - Natural Thorium required per unit of energy production
- **Development and Deployment Risk** (4)
  - Development time
  - Development cost
  - Compatibility with the existing infrastructure
  - Existence of NRC regulations for the fuel cycle and familiarity with licensing
- **Institutional Issues** (2)
  - Compatibility with the existing infrastructure
  - Existence of NRC regulations for the fuel cycle and familiarity with licensing

Subcommittee Observations

- Assessment Is proceeding well
- Dedicated team with good leadership
- There will be an external review before the full evaluation (around April 2013)
- Some of the criteria need a tune up
- Report due before end 2013
- Current assessment Has a missing dimension that can Impact scoring – Reactor Technology
- Need to include uncertainties; some of the criteria are qualitative

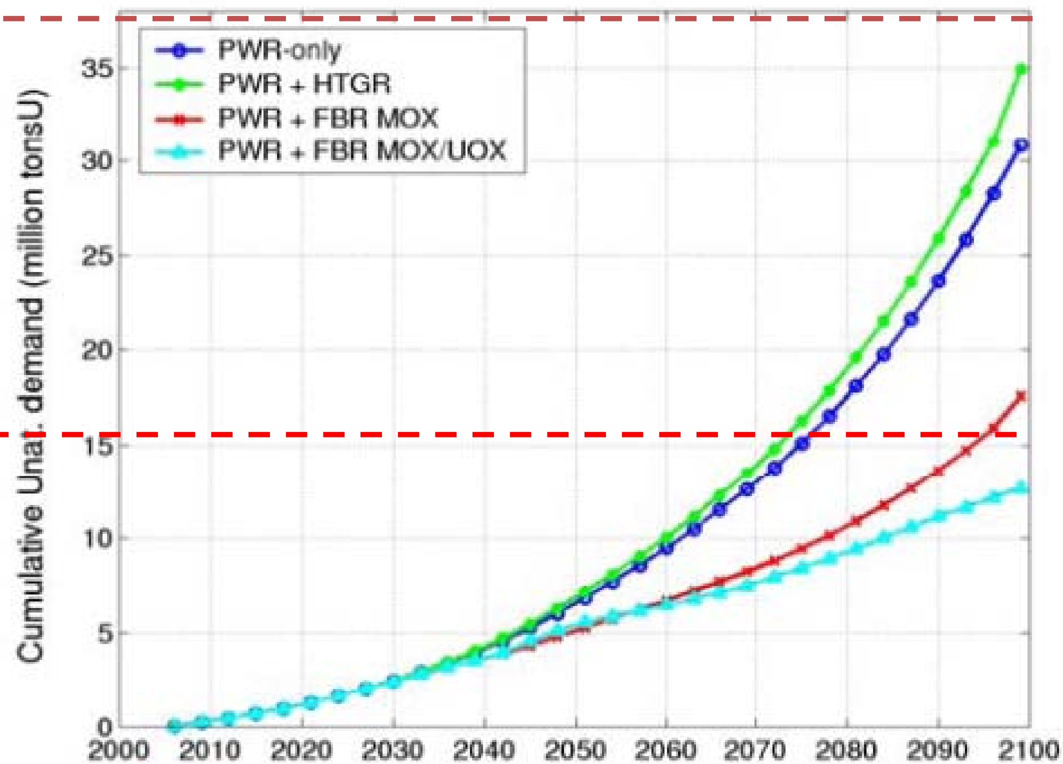
Uranium from Sea Water

Uranium Requirements Through 2100

The figure* presents cumulative **world** uranium consumption for scenarios ranging from once through (30-35 MT) to a transition to breeders beginning in 2040 (13 MT). For this moderate growth scenario, *Redbook resources are exceeded in all but the most aggressive closed fuel cycle case.*

Redbook Resources
+
Phosphates

Redbook Resources



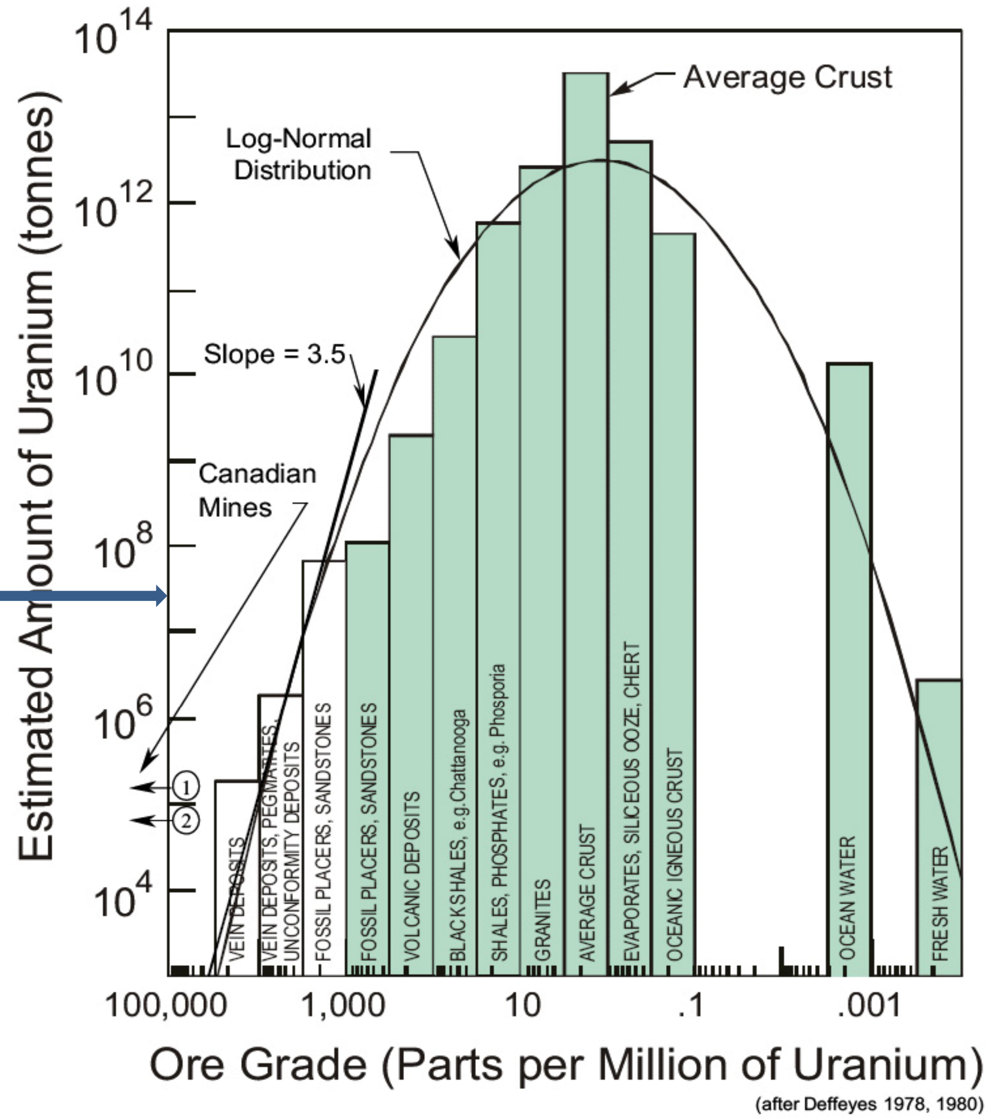
*Carre and Delbecq, “French Fuel Cycle Strategy and Transition Scenario Studies,” *Proc. PHYSOR* 2006.

World nuclear power demand obtained from WEC/IIASA “Global Energy Perspectives” A-3 Scenario.

Courtesy of Dr. Erich Schneider of UT Austin

Crustal Distribution of Uranium by Grade

Red Book



Seawater Uranium Extraction Technology Development in Japan

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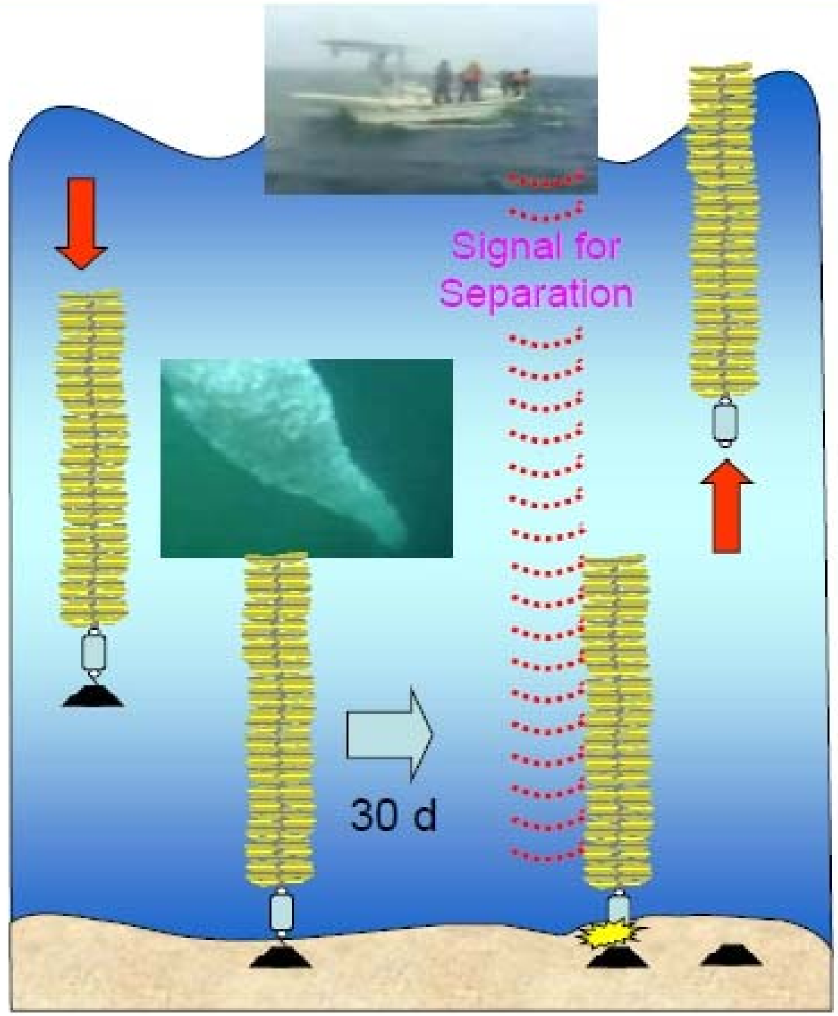
Dr. M. Tamada Presentation 2010

Okinawa Marine Experiment



Subcommittee observations

- Cost – Increase in U above today by $200/kg ups electricity by 0.5 cent/kW-h (implies $350/kg as limit)
- Environmental Issues – You get more than just U absorbed. What happens to the bad stuff including the chemicals used to separate U?
- Are there techniques to extract lower grade ore to get at a larger resource?
- Are the comparative environmental benefits of sea water vs. mining important?
- Progress has been impressive.

Nuclear Fuel Storage and Transportation Planning Project established to respond to BRC recommendations

- **Initial focus consistent with BRC recommendations for near-term actions**
  - Design of consent-based process, technical studies, siting, and preparation for transportation from shutdown sites to a pilot consolidated storage facility
  - Identify and promote opportunities for integration and standardization in waste management system
- **Purpose is to make progress on this important national issue**
  - Build foundation that could be transferred to a new Nuclear Waste Management Organization
- **Activities consistent with BRC recommendations and existing NWPA**

  Constraints (which need updating to do almost anything)
- **Established FY2013**
- **FY2013 Budget: $22M**

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Used Fuel Storage – Background and Status

- **Utilities began to utilize dry storage in the 1980s when fuel pools began to reach capacity and no disposition path was available**
  - Viewed as a temporary solution until a permanent disposal facility was made available
  - Currently, there is a need to store UNF for the foreseeable future

- **UNF Storage Near-Term Challenges**
  - NRC extended storage license – licenses are issued for 20 years, with possible renewals for up to 60 years
    - Technical bases need to be developed to justify licensing
    - Key areas are retrievability and transportation of UNF after long-term storage
  - Transportation of high burn-up fuel
    - Limited U.S. experience with storage and transportation of high-burnup fuel (>45 GWD/MTU)
  - "Stranded" fuel at shut down reactor sites


INL Dry Storage Characterization (DSC) Project

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Storage Systems Used at Shutdown Sites

Reactor Site (Shutdown Date)	ISFSI Load Dates	Storage System / Canister(s)	Transport Cask Status	Total Casks Fuel/GTCC	Total Assemblies
Big Rock Point 8/97	12/02-03/03	Fuel Solutions W150 Storage Overpack / W74 Canister	TS-125 Certificate expires 10/31/12. Never fabricated	7/1	441
Connecticut Yankee 12/96	05/04-03/05	NAC MPC / MPC-26 and MPC-24 canisters	NAC-STC Certificate expires 5/31/14. Foreign use versions fabricated.	40/3	1019
Maine Yankee 8/97	08/02-03/04	NAC UMS / UMS-24 canister	NAC-UMS Certificate expires 10/31/12. Never fabricated	60/4	1434
Yankee Rowe 9/91	06/02-06/03	NAC MPC / MPC-36 canister	NAC-STC Certificate expires 05/31/14. Foreign use versions fabricated.	15/1	533
Rancho Seco 6/89	04/01-08/02	TN NUHOMS/FO-DSC, FC-DSC, FF-DSC	NUHOMS MP-187 Certificate expires 11/30/13. One cask fabricated. No impact limiters.	21/1	493
Trojan 11/92	12/02-09/03	TranStor Storage Overpack Holtec MPC-24E and MPC24-EF canisters	HI-STAR 100 Certificate expires 3/31/14. Units fabricated, No impact limiters.	34	780
Humboldt Bay 7/76	08/08-12/08	Holtec HI-STAR HB / MPC-HB (MPC-80)	HI-STAR HB Certificate expires 3/31/2014. Fuel in fabricated casks. No impact limiters.	5/1	390
La Crosse 4/87	07/12-09/12	NAC MPC-LACBWR / MPC-LACBWR canister	NAC-STC Certificate expires 5/31/2014. Foreign use versions fabricated.	5	333
Zion 1 and 2 7/98	Planned 2013	NAC MAGNASTOR / TSC-37 canister	NAC MAGNATRAN License under review. Never Fabricated	61/TBD (estimated)	2,226

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Recent noteworthy activities

- **9/25-26 – Conducted contractor Progress Review meetings related to Task Order 11 – design concepts for Consolidated Storage Facility**
  - Energy Solutions, Shaw and Areva

- **Week of 9/24 – Awarded contracts to Areva and Energy Solutions related to Standardized Canisters**

- **10/3-4 – Meeting with State Regional Group Staff and Committee Chairs to plan FY13 Transportation Institutional activities**

- **10/17 – Presentations to NWTRB**
  - *Logistical and Operational Issues Associated with the Transport of Stranded Fuel*, J. Williams
  - *System Architecture Evaluation*, M. Nutt

- **10/23 – Presentation to NTSF (National Transportation Stakeholders Forum)**
  - *Department of Energy Transportation and Storage Activities*, J. Williams

Subcommittee Observations

- The project is going in the right direction in laying the ground work for consolidated interim storage and transportation of the used fuels from the shut down sites
- In light of the Fukushima accident, attention should also focus on moving the SNF with the highest density packing in wet pools to dry cask storage. Is this a DOE or NRC issue?
- It is important to determine the integrity lifetime of all containers for dry cask interim storage. Some time ago, DOE did a study the integrity of old fuel-containing canisters stored at INL. Perhaps it is time for another look.

What to do with the Used Fuel Inventory

- **Assuring support for DOE-NE FCT mission**
  - Quantity sufficient to accommodate projected RD&D needs and practical considerations
  - Access to a representative sample of diverse commercial UNF inventory to support UNF storage, transportation, and disposal
  - Access to high-burnup UNF representative of future discharges in quantities sufficient to support fuel cycle technology development
- **Retention of sufficient margin to provide assurance that future retrieval from disposal will not be necessary for research or reuse purposes**
- **Timeframe, material needs, projections for energy growth, and cost considerations to deploy potential alternative fuel cycles**
  - For example, evaluated Pu needs to support fast reactor deployment
- **Possible uses of UNF to support national security interests**

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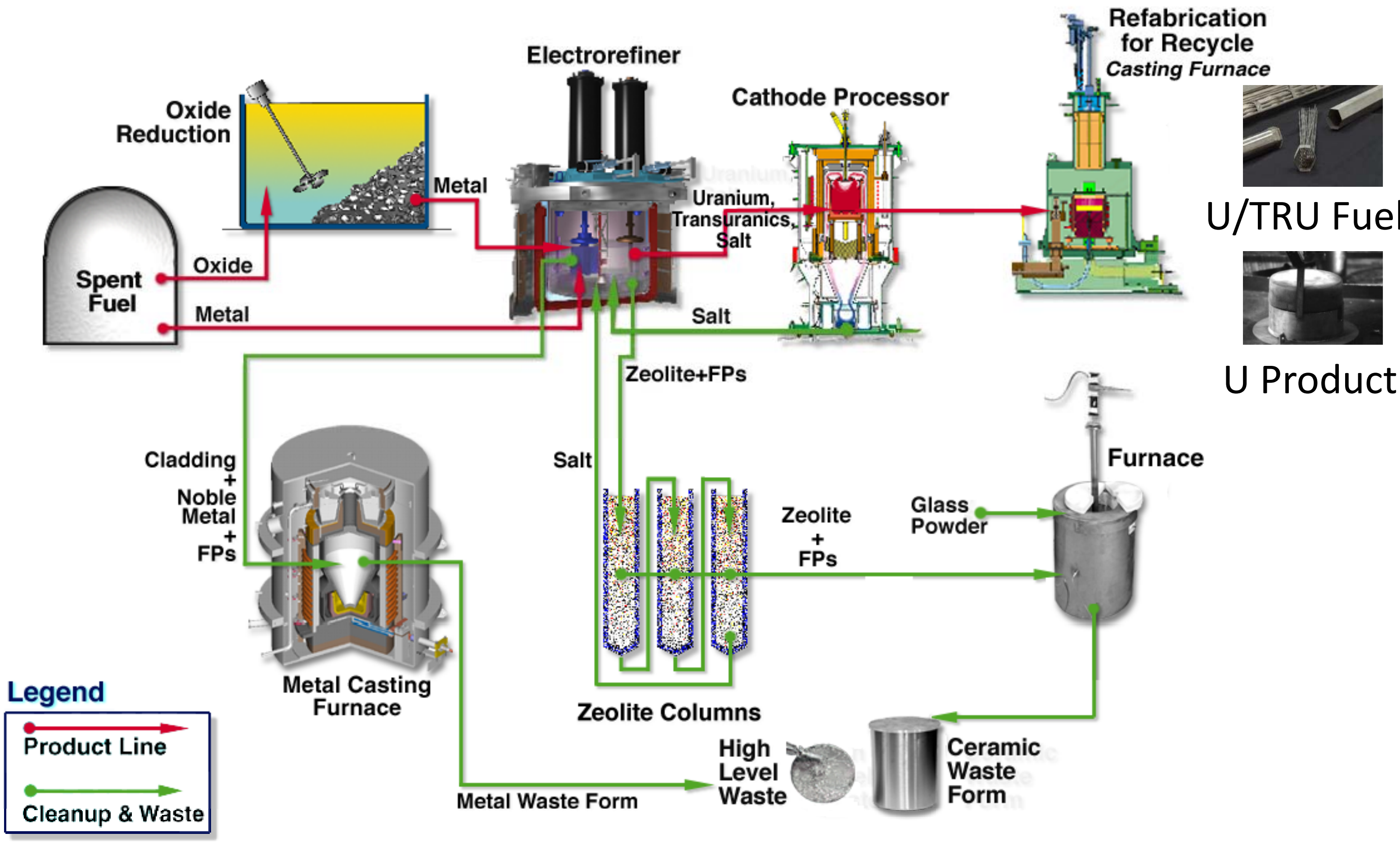
Assessment Supports a Comprehensive National Nuclear Fuel Cycle Strategy

1. Disposes ~98% of the total current inventory (by mass)
   - UNF can proceed to permanent disposal without the need to ensure post-closure retrievability for reuse or research purposes
2. Does not preclude the option of recycling at a future date
   - Since ~2000 MTHM of commercial UNF is generated annually and could provide the feedstock needed for deployment of alternative fuel cycles
3. Retains a small fraction ~0.04% (by mass; excess HEU UNF) with inherent and/or strategic value for potential recycle
   - Supporting national security missions
4. Retains ~ 2.4% (by mass) to support RD&D needs for:
   - UNF management and alternative fuel cycle development
5. An appropriate portion of the UNF generated in the future will be evaluated for potential benefits of reprocessing

Simplified Electrochemical Flow-sheet



- Program focusing on critical path issues

- High recovery efficiency and throughput are necessary, although the fast spectrum reactor can accommodate impurities in metal fuel (except for some Lns); lab-scale tests of spent ternary fuel (10% Zr) has shown that actinide dissolution efficiencies of >99.9 wt % can be obtained.

- Electrochemical technology development activities associated with EBR-II fuel treatment (demonstrated at 1 t/year throughput) may be helpful for improving the feasibility of EC processing and fabrication of metal fuels for recycle in fast reactors.

Subcommittee Observations

- There are science issues (e.g. lanthanide separation) as well as technical ones. Engaging the universities via NEUP could be helpful.
- EC technology is advancing – not yet at the point of assessing the viability of this technology compared to aqueous process
- International collaboration (especially with South Korean KAERI in this field) should be pursued and reinforced.
- Will have to eventually have an engineering scale test