U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Fuel Cycle Research and Development

Examples of Fuel Cycle Options

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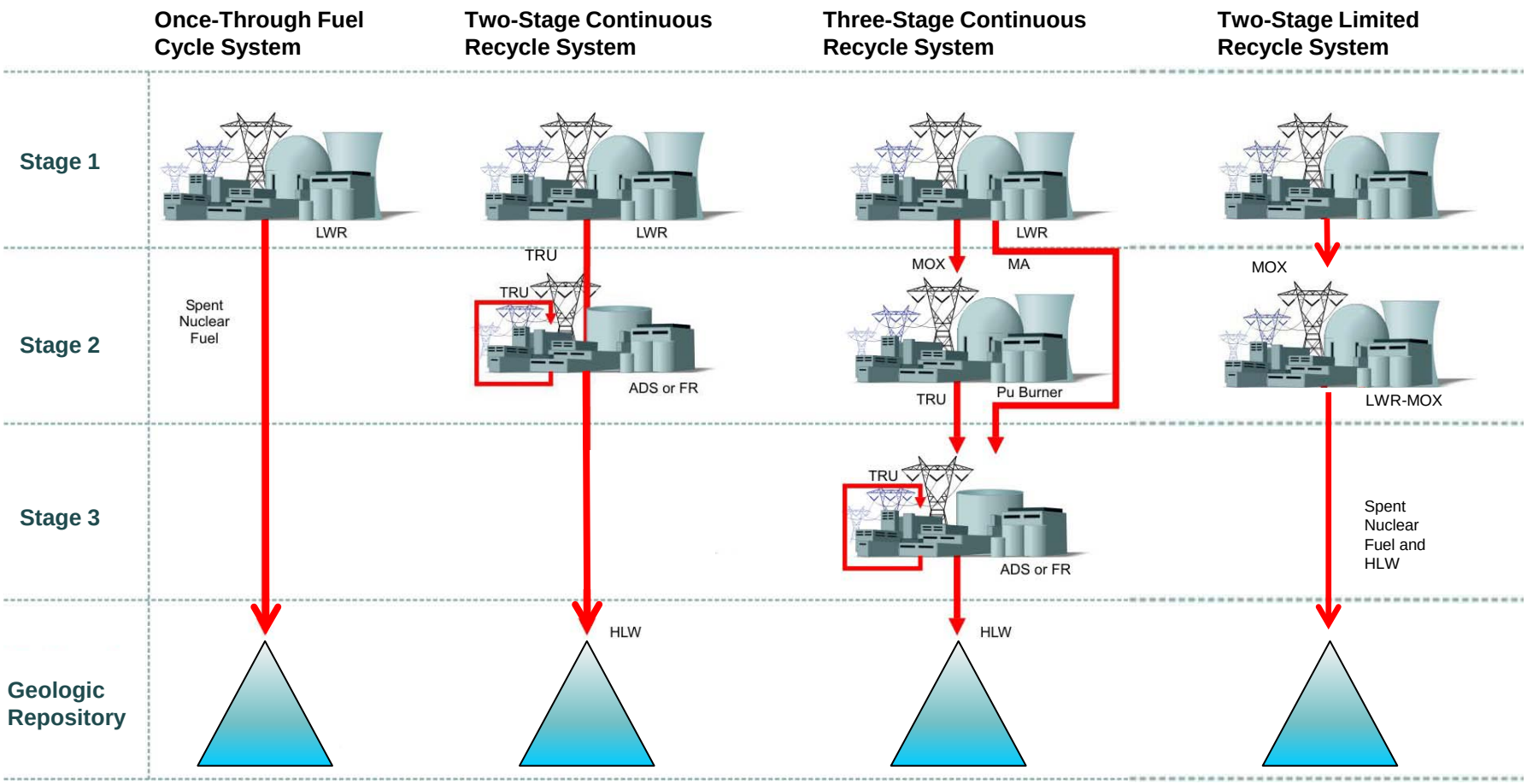
Presentations

1. **Purpose and Objectives of the 2013 Evaluation and Screening Effort**
   - Background
   - Context
   - Overall Process
2. **Fuel Cycle Characteristics Affecting Performance**
3. **Approach for Development of Sets of Fuel Cycle Options and Groups**
4. **Examples of Fuel Cycle Options**
5. **Process for Submitting Fuel Cycle Concepts**
   - Role of Participants
   - Requested information
   - Steps of the Process

Content of Input from Participants

- A purpose of this meeting is to collect top level information on sufficiently unique fuel cycle concept(s) of importance to a participant
- Process for submitting a concept will be discussed in the next presentation
- Examples on the following slides illustrate the types of information that can be provided

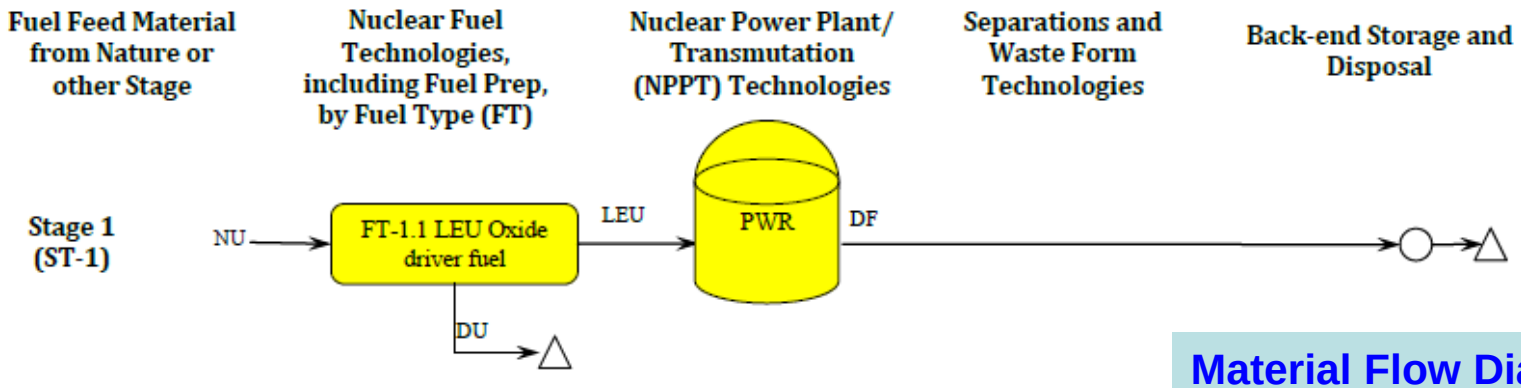
Examples of Fuel Cycle Systems



Once-Through Option: LWR (1-Stage)

Equilibrium State Fuel Cycle Option Description

- **Low enriched uranium (LEU) oxide fuel is irradiated in current commercial PWR to an average discharge burnup of approximately 50 GWd/t; Discharged fuel (DF) is cooled in on-site spent fuel storage and sent to geologic disposal.**



Material Flow Diagram

Note: Low-Level Waste (LLW) will be produced in performing various fuel cycle functions.

Legend:

NU = Natural Uranium
DU = Depleted Uranium
DF = Discharged Fuel
LEU = Low-enriched Uranium
PWR = Pressurized Water Reactor
△ = Nuclear Waste Disposal Technologies
○ = Nuclear Material Storage Technologies
→ = Nuclear Material Transport Technologies

Limited Recycle Option: Breed and Burn with Fuel Reconditioning (1-Stage)

Equilibrium State Fuel Cycle Option Description

- **The Breed and Burn (B&B) sodium-cooled fast reactor is continuously fed with depleted uranium (DU) in metallic fuel and refueled with its own reconditioned fuel. It operates with 8 batches fuel management scheme with fissile conversion ratio (CR) greater than unity. At the end of a cycle, one out the eight fuel batches is discarded when the accumulated average burnup is ~500 GWd/MT. The discarded fuel is replaced with a DU fuel. Additionally, three out of the eight fuel batches are reconditioned individually with the melt-refining process, in order to overcome the cladding radiation damage limit. Recovered fuel contains Transuranics (TRU), uranium (RU) and partial fission products (FPs). Non-recovered actinides and FPs are stored before sent to a disposal site. The discarded fuel is stored and then sent to a disposal site.**

- **To maintain criticality, only the initial core requires low enriched uranium (LEU) driver and DU blanket.**

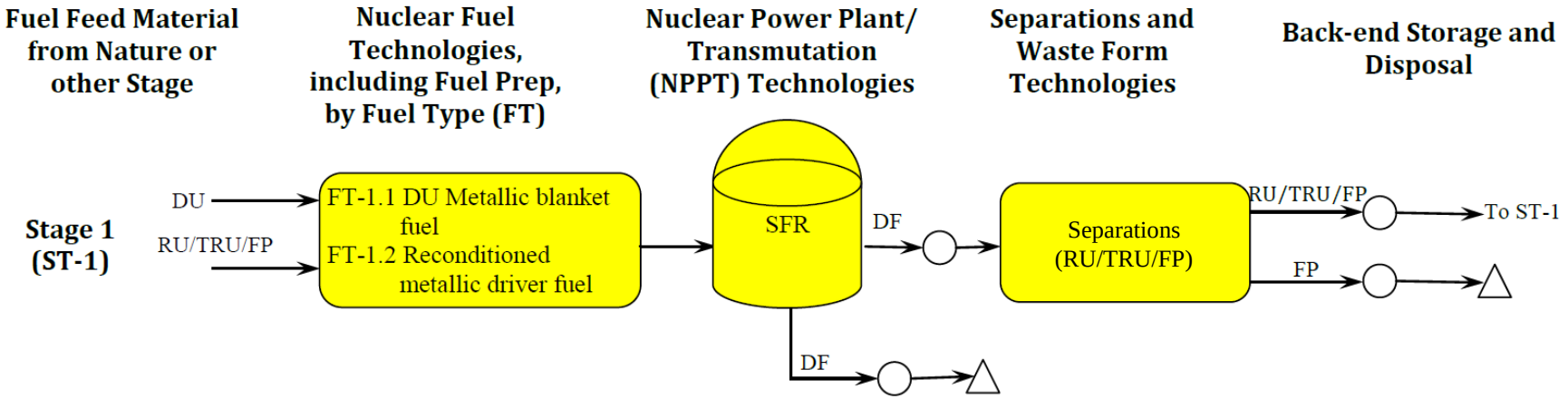
Even-though the description is for equilibrium state of the fuel cycle, it however notes the fuel for the initial start-up system

Limited Recycle Option: Breed and Burn with Fuel Reconditioning (Cont'd)

Fuel Cycle Data Package (FCDP) | **System Datasheet** | B&B with fuel reconditioning

Breed and Burn with fuel reconditioning

Material Flow Diagram



Note: Low-Level Waste (LLW) will be produced in performing various fuel cycle functions.

Legend:

DU = Depleted Uranium
SFR = Sodium-cooled fast Reactor
RU = Recovered Uranium
DF = Discharged Fuel
TRU = Transuranics
FP = Fission Products

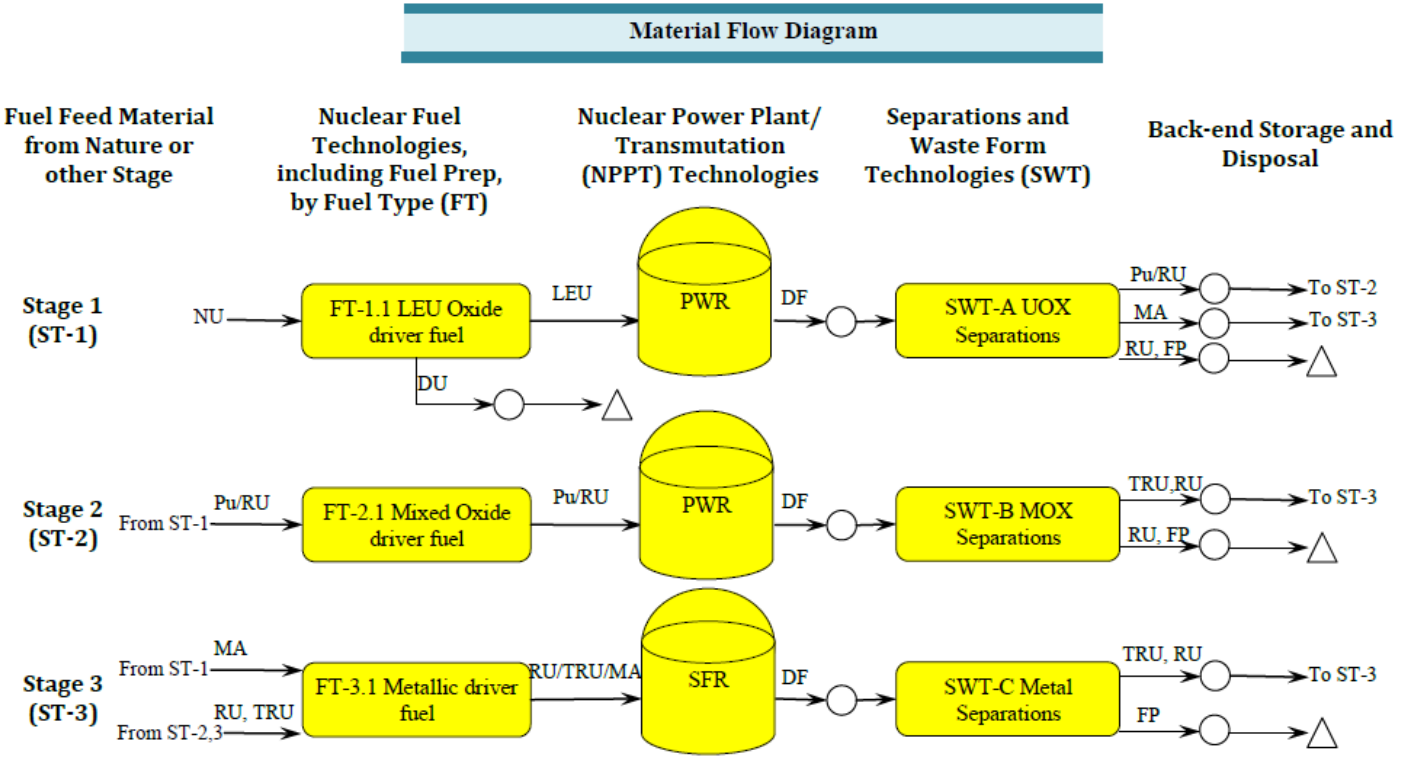
△ = Nuclear Waste Disposal Technologies
○ = Nuclear Material Storage Technologies
→ = Nuclear Material Transport Technologies

Example Continuous Recycle Option: PWR-UOX to PWR-MOX to SFR (3-Stage)

Equilibrium State Fuel Cycle Option Description

- **In Stage 1, LEU oxide fuel is irradiated in PWR until burnup of 50 GWd/t. Discharge fuel (DF) is stored and then reprocessed. Plutonium (Pu) and uranium are co-extracted. Recovered Pu and uranium (RU) are sent to Stage 2. Recovered minor actinides (MAs) are sent to Stage 3. Fission products (FPs) are stored and then sent to a disposal site.**
- **In Stage 2, Recovered Pu and RU from Stage 1 are used to make mixed (uranium/plutonium) oxide fuel. The Pu/RU mixed oxide fuel is irradiated to a burnup of 50 GWd/Mt in PWRs. DF is stored and then reprocessed. Recovered Transuranics (TRU) and some RU are sent to Stage 3. FPs are stored and then sent to a disposal site.**
- **In Stage-3, Recovered TRU and RU from Stage 3, recovered TRU and RU from Stage 2, and recovered MA from Stage 1 are used to make TRU/RU metallic fuel. The metallic fuel is irradiated to average discharge burnup of 92.4 GWd/t in SFR burner with a medium TRU conversion ratio of 0.82. DF is stored and reprocessed for recycle. FPs are stored and then sent to a disposal site.**

Example Continuous Recycle Option: PWR-UOX to PWR-MOX to SFR (Cont'd)



Note: Only primary material flows are shown. Material flows from imperfect separations (losses), Low-Level Waste (LLW), and other secondary streams that will be produced in performing various fuel cycle functions are not shown.

Legend:

NU = Natural Uranium	DF = Discharged Fuel	PWR = Pressurized Water Reactor	△ = Nuclear Waste Disposal Technologies
DU = Depleted Uranium	FP = Fission Products	SFR = Sodium-cooled Fast Reactor	○ = Nuclear Material Storage Technologies
LEU = Low-enriched Uranium	TRU = Transuranics	MOX = Mixed Oxide	→ = Nuclear Material Transport Technologies
RU = Recovered Uranium	MA = Minor Actinides	UOX = Uranium Oxide	

Fuel Cycle Concepts Submitted

- **Descriptive and material flow information provided by a participant should have sufficient detail to allow understanding of the fuel cycle concept**
  - No calculated data, e.g. mass flow data, is explicitly requested, but can be provided if needed for clarity
- **Information will be reviewed and if necessary clarification will be sought**
- **All submitted concepts will be documented and additionally considered for further evaluation**
- **Intent is to ensure a comprehensive set of options for the evaluation and screening**

Fuel Cycle Data Development

- **Overall development process is extensive and needed for evaluation and screening**
  - Fuel cycle systems data and mass flow data are collected into fuel cycle data packages and stored in a fuel cycle catalog
  - Calculation results and references are documented and provided various levels of independent reviews
  - Metrics data are given special attention

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Fuel Cycle Data Packages Being Developed for Fuel Cycle Options

- **Philosophy**
  - Provide high-level system description data consistent with need of the Catalog*
  - Detailed information is contained in reports assessing fuel cycle systems or metrics
  - References to calculation reports and detailed analysis, and the provision of electronic version of references
- **Fuel cycle data and metrics data supporting the evaluation and screening will be developed by the FCR&D program team**
- **Structure of FCDP:** System datasheets contain option-dependent data, and supporting technology datafiles contain technology data

System Datasheets
- Summary description
- Material flow diagram
- High-level parameter data
- Fuel cycle performance summary – calculated metrics
- Mass flow data
- References

Technology Datafile
- Summary description
- Schematic diagram and pictures
- High-level parameter data
- References

**Catalog is a repository for fuel cycle information*