U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Nuclear Energy University Programs (NEUP)

Fiscal Year (FY) 2013 Annual Planning Workshop Webinar

Fuel Cycle Option Analysis

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Overview

- Overview of Program Area (where it fits within the overall DOE strategy);
- Program Organization Structure (including leadership, collaborators, etc.); and
- Program Mission/Objectives/Goals (near-term and long-term).

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Organization Structure

NE-5
Deputy Assistant Secretary for Fuel Cycle Technologies

Robert Price
NE-51
Systems Engineering And Integration

- Fuel Cycle Options Analysis (FC-5)

Andrew Griffith
NE-52
Fuel Cycle Research and Development

- Sep/ Waste Forms (FC-1)
- Advanced Fuels (FC-2)
- Nuclear Materials
- Safeguarding and Instrumentation (FC-3)

Bill Boyle
NE-53
Used Nuclear Fuel Disposition Research and Development

- Used Fuel Storage and Transportation (FC-4.1)
- Used Fuel Disposal (FC-4.2)

Bill Szymanski
NE-54
Uranium Management and Policy

Fuel Cycle Options Campaign Mission and Objectives

Mission

Develop and implement analysis processes and tools and perform integrated fuel cycle technical assessments to provide information that can be used to objectively and transparently inform and integrate Office of Fuel Cycle Technologies activities.

Vision

By 2016, the Fuel Cycle Options campaign will have defined a small number of fuel cycle options and associated technologies that have the potential to provide major improvements over the current fuel cycle and related technologies, and have determined the R&D and research facilities needed to make these technologies available for commercialization.

Fuel Cycle Options Involves an Integrated Approach

Front End **Back End**

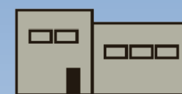
Uranium Resources

- Conventional production
- Innovative approaches
  - U Seawater

Fuel Fabrication

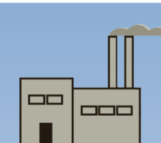
- Safety enhanced LWR fuel
- Higher performance
  - Improved burnup
  - Accident tolerance

Reactors



Interim Storage

- Evaluating extended time frames
- Transport after storage



Recycle

- Separations
- Recycled fuel
- Secondary waste treatment

Disposal

- Alternative geologies
- Alternative waste forms

Integrate, focus, prioritize through systems analysis and engineering

Fuel Cycle Option Analysis FC-5

- **The Fuel Cycle Options Campaign performs analysis and evaluates integrated fuel cycle systems with the purpose of identifying and exploring sustainable nuclear fuel cycles that are candidates for future deployment. Results of these studies and R&D activities must be effectively disseminated to program stakeholders and the public in an accurate, open, and simple manner.**

Focus of the FY13 research:

- **Support population of the Fuel Cycle Catalog**
- **Support development of the Fuel Cycle Simulator**

Fuel Cycle Options Analysis (FC-5.1) Focus Areas for Fuel Cycle Catalog

- The FCT Fuel Cycle Catalog will serve as a repository for technical information on fuel cycle system performance along with related technologies.

The Catalog will:

- Be accessible to public and serve as an education and communication tool;
- Will not contain any classified, sensitive, or proprietary information;
- Be comprehensive in terms of possible fuel cycle system performance;
- Contain the information used for the 2013 Evaluation and Screening; and
- Peer-reviewed.

Fuel Cycle Catalog (FC-5.1)

- **Proposals to develop Fuel Cycle Data Packages (FCDPs) for fuel cycles in any or all of the following fuel cycle groups will be considered for awards:**
  - *Multi-stage* fuel cycle options using *only* thermal reactors, with the attribute for significantly reducing actinide content of nuclear waste;
  - *Multi-stage* fuel cycle designed for continuous recycle of actinides using *only* fast reactors; and
  - Fuel cycles using targets containing transuranic elements and/or fission products for reducing their content in nuclear waste.
- **The Program Office will provide**
  - A Fuel Cycle Data Package template that defines the information that needs to be provided;
  - The analysis assumptions to be used; and
  - Definitions of the evaluation criteria and performance metrics.

FCDP Template

Philosophy

- Provide high-level system description data consistent with need of the Catalog;
- Detailed information is contained in reports assessing fuel cycle systems or containing calculations of fuel cycle metrics;
- References to calculation reports and detailed analysis, and the provision of electronic version of references; and
- System datasheet contains option dependent *specific* information, while technology datafile contains *Wiki-style* technology information.

Structure of FCDP

System Datasheets

- Summary Description
- Material Flow Diagram
- High-level Parameter Data
- Evaluation Criteria and Metrics
- Mass Flow Data
- Transition and Scenario Analysis Data (optional)
- References

Technology Datafiles

- Summary Description
- Schematic Diagram and Pictures
- High-level Parameter Data
- References

FCDP System Datasheet: Example Summary Description

Fuel Cycle Data Package (FCDP) **System Datasheet** PWR-UOX/PWR-MOX/SFR

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Summary Description

Fuel Cycle Option No.	TBD	**Roadmap Strategy**	Full Recycle	**Recycle Strategy**	Continuous Recycle
Fuel Cycle Option Title	PWR-UOX to PWR-MOX and to SFR-burner for full recycling				
Revision number	**Revision remarks**				
Rev. 0.0 Rev. 0.1 Rev. 0.2	Initial Revision Revised due to changes of references and FCDP template version (rev. 0.1) Adopted feedbacks from Assumption Document Review Meeting, Las Vegas, 3/27/2012				
High-level Objective(s)	1) Produce electricity 2) Manage waste disposal by partitioning and/or transmuting actinide isotopes 3) Can utilize existing thermal reactor infrastructure 4) Provide input as needed				
No. of Stages 3	**Stage Description**				
Stage 1 UOX fuel PWR (Separation - TBD)	LEU oxide fuel is irradiated in PWRs 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) and excess RU are stored and then sent to a disposal site(s).				
Stage 2 MOX fuel PWR (Separation - TBD)	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 uranium (RU) are sent to Stage 3. FPs and excess RU are stored and then sent to a disposal site(s).				
Stage 3 Metal fuel SFR Burner (Separation - TBD)	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.				
Prepared by	T. K. Kim (ANL)	**Date**	February 28, 2012		
Internally Reviewed by	E. A. Hoffman	**Approval Date**	February 29, 2012		
Externally Reviewed by		**Approval Date**			
Accepted by	FCDP coordinator	**Acceptance Date**			

FCDP System Datasheet: Example Material Flow Diagram

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Fuel Cycle Data Package (FCDP)

System Datasheet
PWR-UOX to PWR-MOX and to SFR Burner for Full Recycling

PWR-UOX/PWR-MOX/SFR

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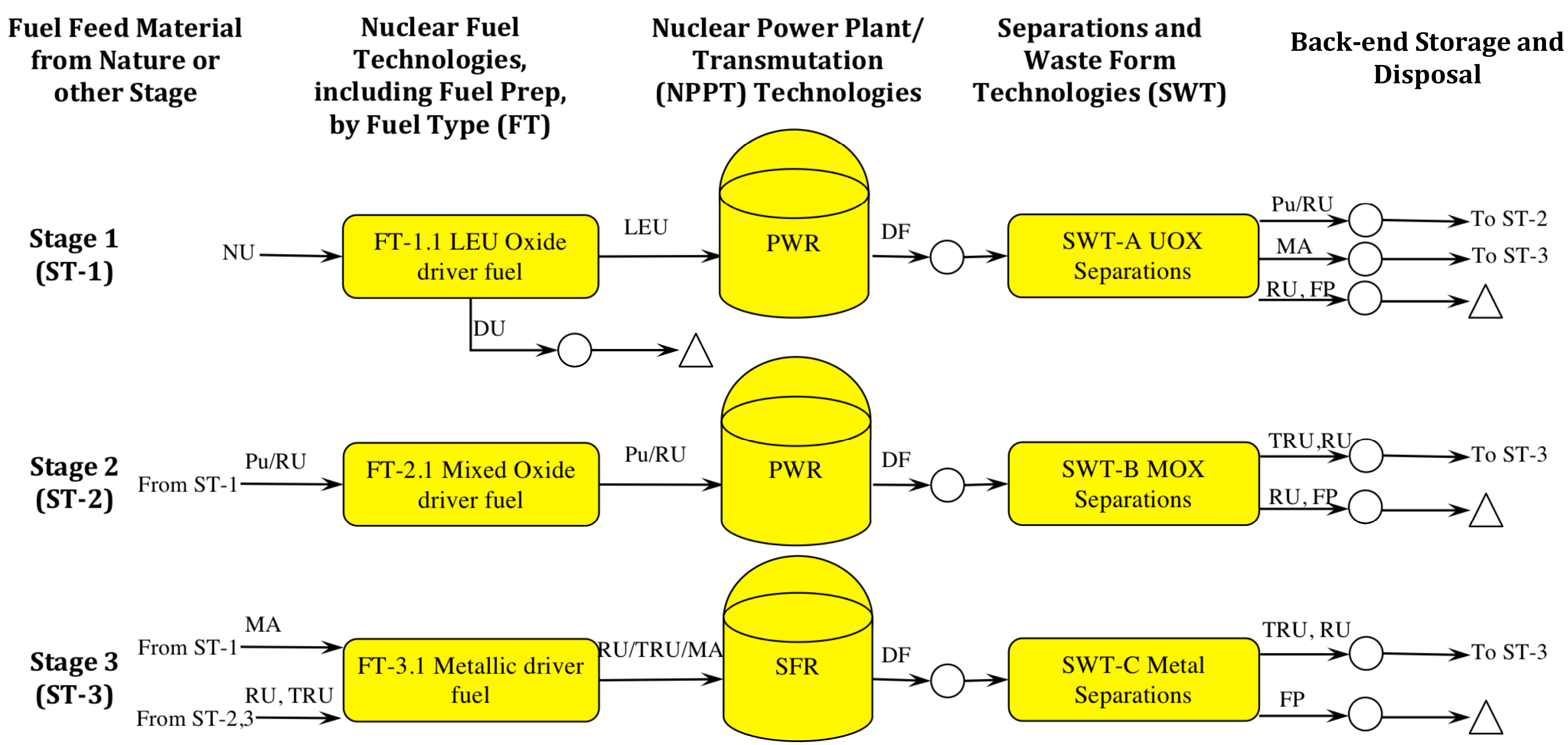
Material Flow Diagram



FCDP System Datasheet: Example Parameter Information

Fuel Cycle Data Package (FCDP) | **System Datasheet** | PWR-UOX/PWR-MOX/SFR

PWR-UOX to PWR-MOX and to SFR Burner for Full Recycling

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Technology category	Parameter		Fuel Type Number (1st digit denotes Stage No.)				
			1.1	2.1	3.1		
Nuclear Fuel	Fuel Technology Identifier		PWR-UOX	PWR–MOX	SFR-Metallic		
	Purpose		Driver	Driver	Driver		
	Chemical Form		Oxide	Oxide	Metal		
	Physical Form		Pin Bundle – Ductless	Pin Bundle – Ductless	Pin Bundle – Ducted		
	Average Discharge Burnup, GWd/t		50.0	50.0	92.4		
	Fuel Composition	Initial Nuclear Material(s)	LEU	Pu/RU	TRU/RU		
		U-235+ U-233/Total U, %	4.21	0.79	0.11		
		Th/Total HM, %	0	0	0		
		TRU/Total HM, %	0	10.7	19.2		
	Non-fissionable Target materials		n.a.	n.a.	n.a.		
	Non-fissionable Target Charge Rate, kg/GWe-yr		n.a.	n.a.	n.a.		
	Non-fissionable Target Transmutation Fraction, %		n.a.	n.a.	n.a.		
	Fabrication Losses, %		0.1	0.1	0.0		
	Separation Process(es) Used as Source		n.a.	A	A,B,C		
	Enrichment Tailing, %		0.25	n.a.	n.a.		
	Fuel Fab. Time and Lag Before Use in NPPT, years		1.0	1.0	0.2		
	Fuel Residence Time in Reactor, years (EFPY)		4.1	4.1	4.7		
	Post Irradiation Time (Decay and Separation if applicable) before Fabrication/Disposal, years		5.0	5.0	0.0		
	Technology Readiness Level (TRL)		9	8	7		
	Brief Justification of TRL:		Commercial Experience	Commercial experience in Europe, but limited in U.S.	TRU fuel was not been qualified completely		
	LLW	from normal operations, m^3/t	TBD	TBD	TBD		
		from D&D, m^3/capacity in t/yr	TBD	TBD	TBD		
	GTCC	from normal operations, m^3/t	TBD	TBD	TBD		
		from D&D, m^3/capacity in t/yr	TBD	TBD	TBD		
	Reference(s)		1, 2	1, 2	1,2		

Note: Repeat table if additional columns are required for additional fuel types.

FCDP System Datasheet: Example Mass Flow Data

Fuel Cycle Data Package (FCDP) | **System Datasheet** | PWR-UOX/PWR-MOX/SFR

PWR-UOX to PWR-MOX and to SFR Burner for Full Recycling

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Mass Flow Data

Stage		**1**			**2**			**3**			**Sum** [b]
Technology		**Fuel**	**NPPT**	**Sep/WF**	**Fuel**	**NPPT**	**Sep/WF**	**Fuel**	**NPPT**	**Sep/WF**	
Electricity, GWe-yr/yr		38.1			4.1			57.8			100.0
Feed or product of nuclear materials (metric ton) [a]											
Natural resource	NU	- 7163.2									- 7163.2
	Th										-
Products from fuel or NPPT technology	DU	+ 6322.1									+ 6322.1
	UOX-LEU	+ 833.9	- 833.9								0.0
	MOX-HM				+ 90.8	- 90.8					0.0
	Metal-HM							+ 570.5	- 570.5		0.0
	DF		+ 833.9	- 833.9		+ 90.8	- 90.8		+ 570.5	- 570.5	0.0
Products from Sep/WF technology	RU			+ 778.7	- 81.2		+ 78.1	- 460.7		+ 412.5	+ 727.4
	Pu			+ 9.8	- 9.8						+ 0.0
	TRU			*) + 1.1			+ 8.0	- 109.8		+ 100.6	+ 0.0
	FP			+ 43.5			+ 4.6			+ 57.4	+ 105.5
Sum (=Loss) [c]		+ 7.2	+ 0.0	+ 0.8	+ 0.1	0.0	+ 0.1	+ 0.0	0.0	+ 0.0	+ 8.2
References		2			2			2			

a) Mass flow in metric ton was developed to produce 100.0 GWe-year from whole nuclear fleet and the signs (-) and (+) indicate the feed and production to or from each technology category, respectively.
b) Summation of each row indicates the required resource (-) or produced nuclear materials (+) per year to generate electricity of 100 GWe-yr.
c) Summation of each column indicates the loss from each technology per each stage.
*) Recovered MA only from PWR-UOX discharge fuel.

Fuel Cycle Options Analysis (FC-5.2) Focus Areas for Fuel Cycle Simulator

- **An open-source Fuel Cycle Simulator is being developed that will enhance the program's ability to educate, communicate, and support decision-making about future fuel cycles and related technologies.**
- **Key university research needs for this activity include:**
  - Develop modules for the fuel cycle simulator that support specific types of fuel cycles or fuel cycle technologies; and
  - Develop capabilities for whole system optimization and economic analyses.

Fuel Cycle Simulator (FC-5.2)

- **The University of Wisconsin is leading development of the Fuel Cycle Simulator**
  - Award made in FY12 NEUP
- **For information about the Fuel Cycle Simulator see http://cyclus.github.com/.**