GNEP Deployment Studies

Presentation to the Department of Energy

April 23rd 2008

The EnergySolutions Team

Introducing the team

TOSHIBA

Shaw® Shaw Environmental, Inc.

Westinghouse

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NFS

AECL

Overview

- Our approach to the studies
- Key features in our deliverables
  - The business plan
  - The technology development roadmap
  - The conceptual design studies
  - The communications plan
- Our conclusions and proposals to move GNEP forward

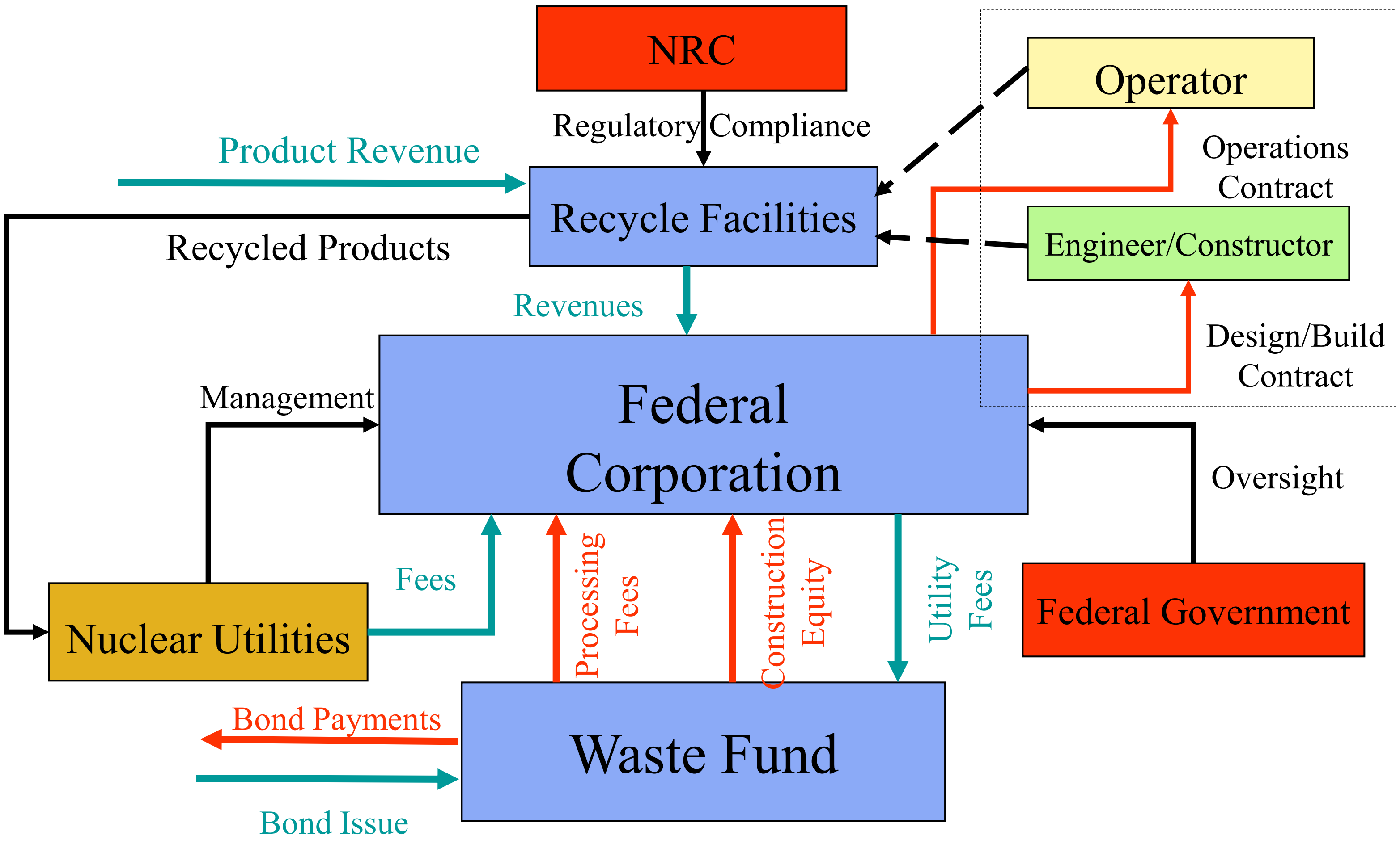
Our Approach

- How to implement the full GNEP vision
  - Improved waste management
  - Meet proliferation goals
  - Recover and recycle uranium and transuranics in new fuel
- Use proven, advanced processes and equipment where possible
- Incremental approach to commercial deployment of GNEP facilities
- Industry's needs drives development activity

Business plan features

- Nuclear cycle modeled thru 2100
- All commercial SNF is available for recycling
- Existing waste fund not ‘practically’ available - initially
- Create a new Waste Fund to finance cap-ex and op-ex for closing the fuel cycle
- Fund managed by new federal corporation
- FedCorp issues bonds as necessary
- 100% private funding of recycling facilities
- Maximize revenues by incentivizing re-use of recovered U/Pu in fuel products in LWRs & CANDUs
- ARRs incentivized via no fuel cost and no waste fee

FedCorp Business Relationships



Business Plan Summary

- No need to use existing Nuclear Waste Fund
- New Government Entity to manage SNF and a new Fund
- Nominal increase in waste fee charged to utilities – 1.95mil/kwh
  - Minimal increase if existing NWF used – 1.25 mil/kwh
- Mil rate most sensitive to U spot price
- Sufficient time allotted for development of ARR
- ARRs incentivized via no fuel cost and no waste fee

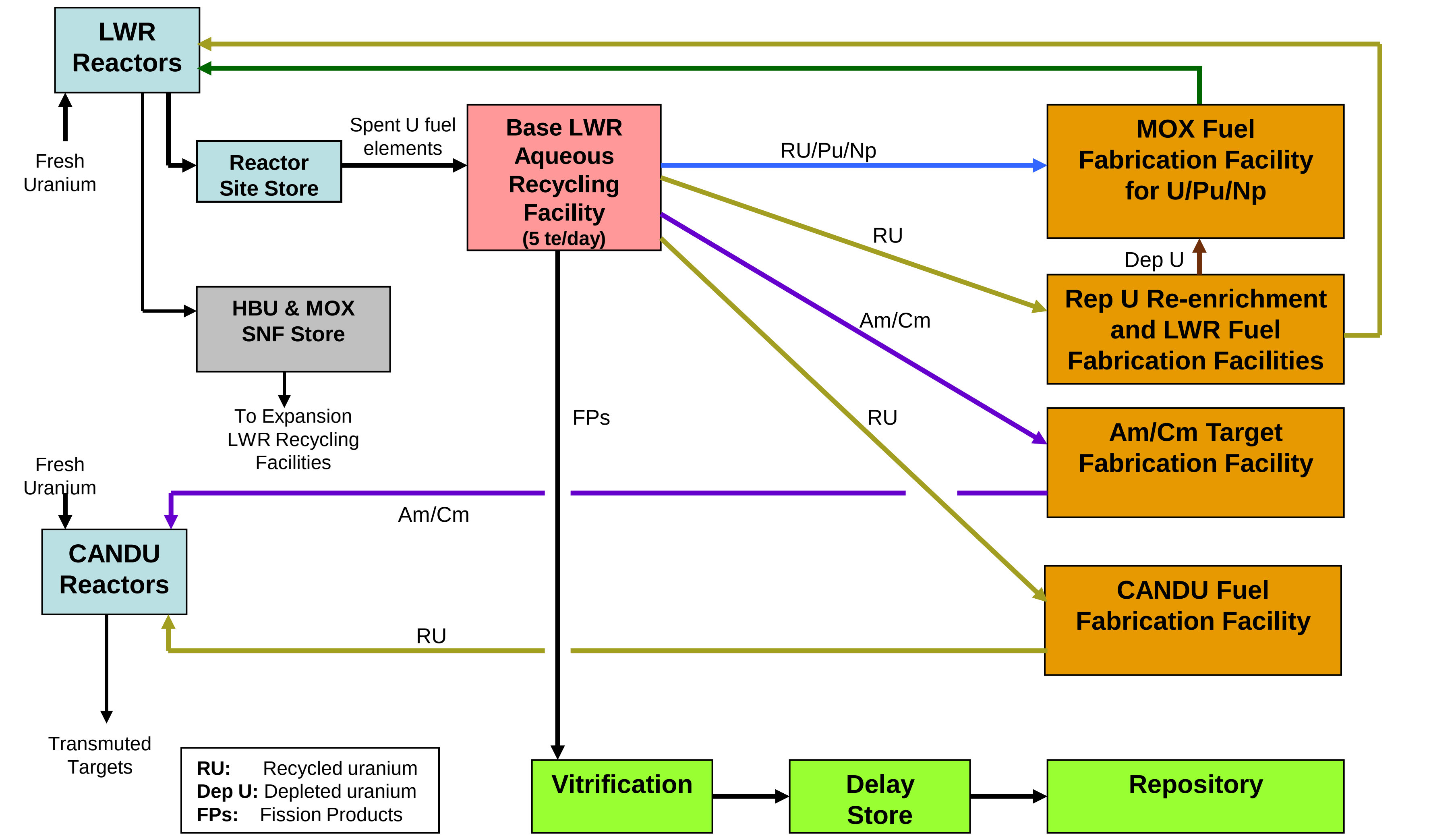
Basis of Technology Development Roadmap

- The Technology Roadmap is designed to support both short and longer term recycling schemes:
  - Short Term Scheme: 2023 to 2035 without ARRs
    - Remaining technology demonstrations to start straight away to support LWR Aqueous recycling operation by 2023
  - Longer Term Scheme: 2035 to 2075 with ARRs
    - Technology development required to support ARRs and Non-Aqueous recycling – needs to start now support Demonstration ARR schedule

- Separation and burning of americium and curium is assumed in the Short Term scheme
  - But we recognize that this is dependent on successful completion of development of separation process and of target manufacture

Short Term Scheme 2023-2035

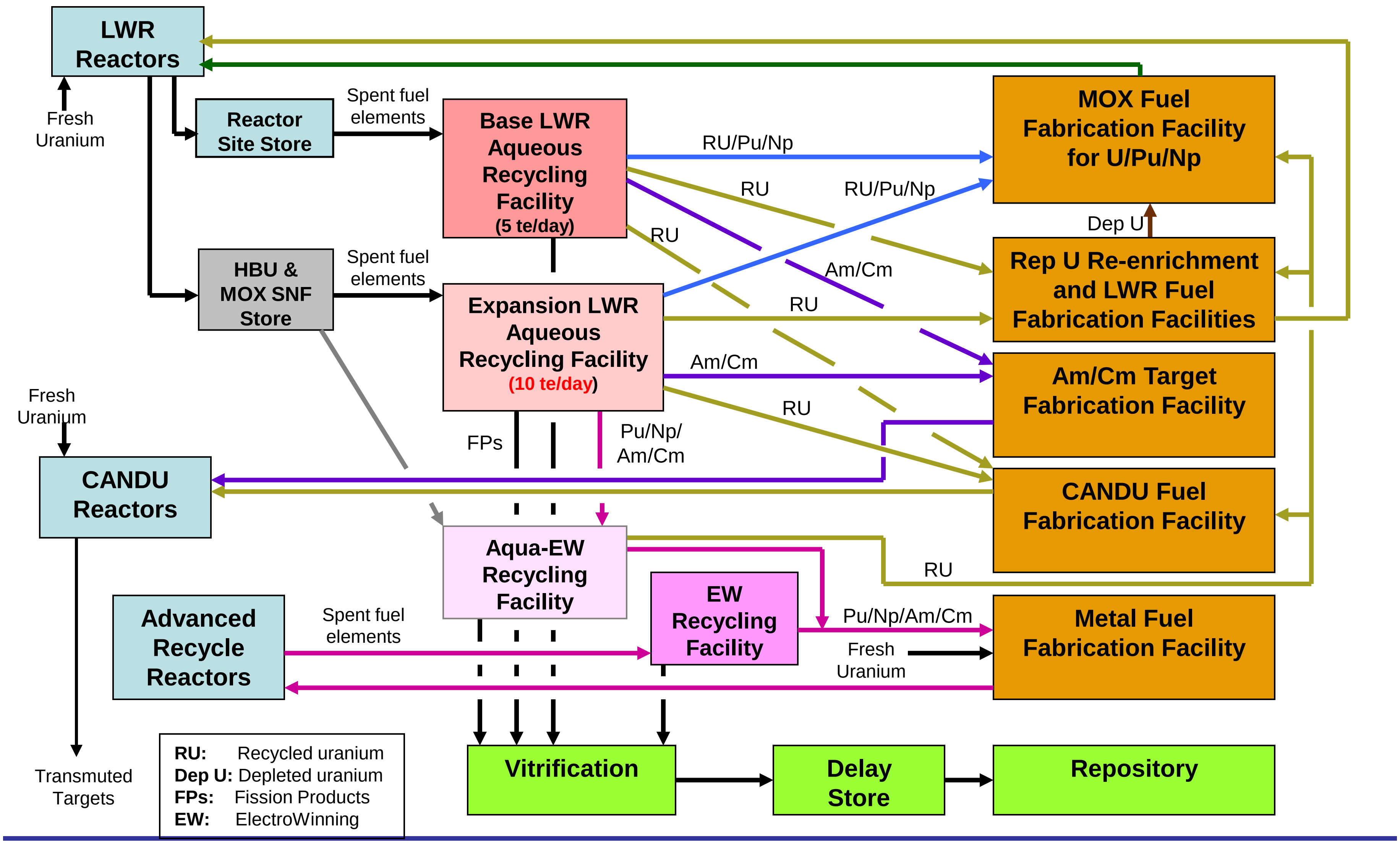
with Am/Cm separation but before ARRs



Longer Term Scheme: with ARRs, 2035 to 2075 and Non-Aqueous Recycling

- Base Aqueous Recycling Facility
  - Same products and destinations as for the Short Term Scheme
  - Same Wastes and destinations as for the Short Term scheme
- Expansion Aqueous Recycling Facilities
  - Generally the same as Base Recycling Facility
  - Development & design to allow HBU and MOX fuels to be processed efficiently
  - Development & design to increase capacity, reduce plant footprint
- Advanced Reactor Systems
  - Fast neutron, metal fueled, liquid metal cooled reactors
  - Metal fuel fabrication facility
  - Non-aqueous recycling facility using Electro-Winning (EW)
- Possible Aqua-EW Facility
  - Aqueous front end to remove uranium
  - Then oxalate precipitation, chlorination, EW
  - Could replace one of more of the Expansion Aqueous Recycling Facilities – if development work is sufficiently advanced

Longer Term Scheme: with ARRs, 2035 to 2075 and Non-Aqueous Recycling



NASA Technology Readiness Levels

TRL	Definition	Description
1	Basic principles observed & reported	Lowest level of technology readiness. **Scientific research** begins to be translated into applied research and development.
2	Technology or process concept or application formulated	**Invention begins**. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis
3	Analytical and experimental critical function and/or proof of concept	**Research and development is initiated**. This includes analytical studies and laboratory studies to physically validate predictions of separate elements
4	Component and/or assembly validation in laboratory environment	Basic technological components are integrated to establish that they will work together. "Low fidelity" compared to the eventual system. **Typically inactive or trace active lab testing**
5	Component and/or assembly validation in relevant environment	Higher fidelity. The basic technological components are integrated with more realistic supporting elements so they can be tested in a simulated environment. **Typically glovebox testing with "spiked" radionuclides.**
6	System/subsystem model or prototype demonstration in a relevant environment	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. **Typically large scale low active pilot plants**
7	System prototype demonstration in an operational environment	Prototype near planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment. **Typically fully-hot testing at small to medium scale**
8	Actual system completed and qualified through test & demonstration	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. **Typically would be completion of cold commissioning of a system before going hot**
9	Actual system proven through successful mission operations	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. **This would typically be initial hot operation of a recycling facility**

Technology Readiness levels

Technology Area		Technology Readiness Level
LWR Aqueous Recycling		6-9
Non- Aqueous Recycling	Aqua-EW	3-9
	Electro-Winning for ARR Fuel	1-6
Fuels and Reactors	Fuel Fabrication and Use	3-9
	RU Re-Enrich	4-9
	Am/Cm Target Fabrication	3-6
	ARR with Metal Fuel	1-8
	CANDU Reactor Ops	4-9

Nuclear Fuel Recycling Center

Scope of the Nuclear Fuel Recycling Center

- Design Build, Start up and Operate the following Facilities:
  - Initial LWR Recycling Center with 1500 MT/yr capacity
  - Initial MOX Fuel Fabrication Facility with 300 MT/yr capacity
  - Optional Am/Cm Target Fabrication Facility with 1.5 MT/yr capacity
  - Associated solid and liquid Waste Treatment Facilities with 4500 MT/yr capacity

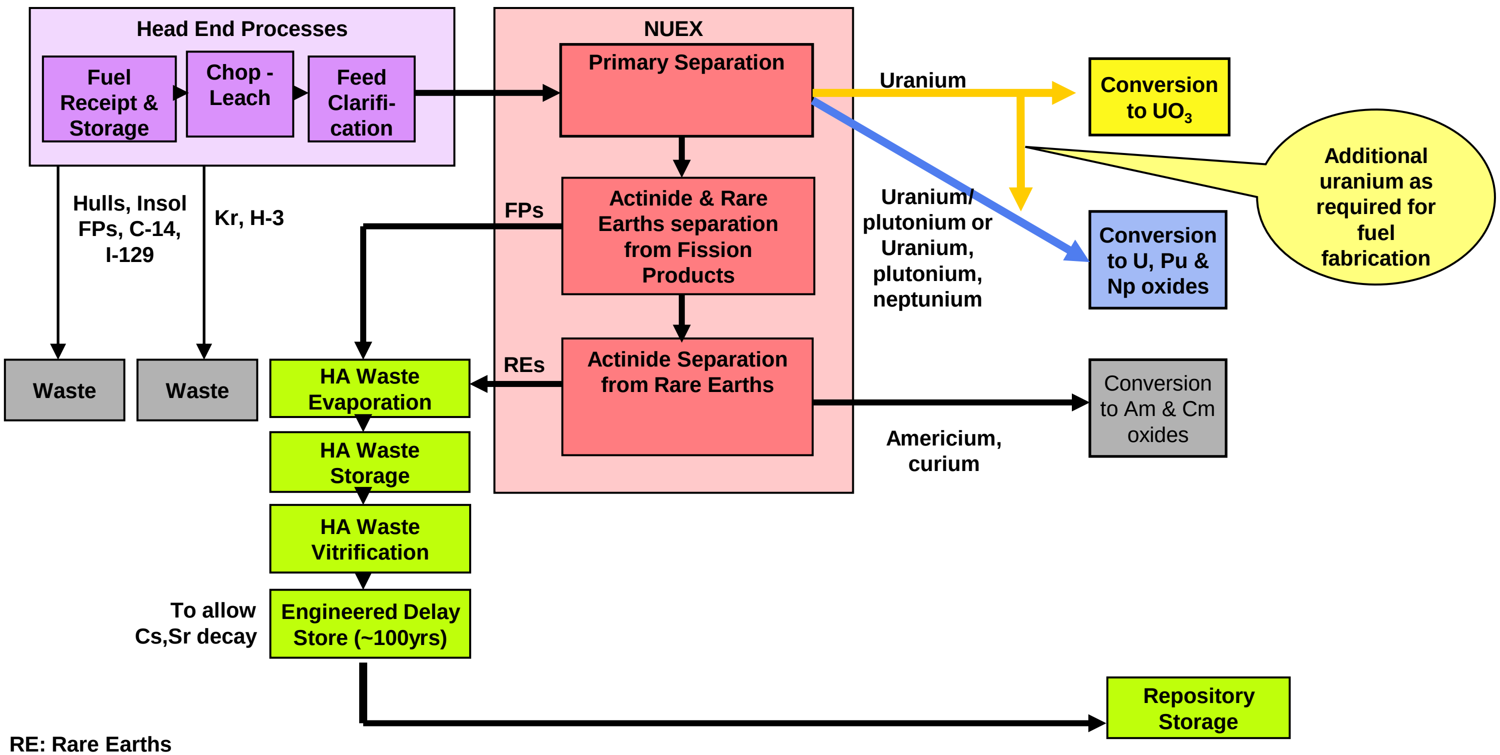
- Site Plan includes for co-located Expansion LWR Recycling Center with 3000 MT/yr capacity, capable of recycling HBU and MOX fuels, with associated MOX Fuel Fabrication Facility

- Initial LWR Recycling Center, MOX Fuel Fabrication and associated Waste Treatment Facilities are **not first of a kind:**
  - Based on commercially deployed technology
  - Will incorporate features to support GNEP goals
  - Will incorporate lessons learned from previous generations of operating facilities

Key Design and Operational Assumptions

- The NUEX flowsheet produces uranium & mixed transuranic products with or without uranium. Pure plutonium never separated
- Initial recycling facility will process 50GWd/MT spent fuel. Expansion facilities will process material with burn ups up to 60GWd/MT
- HLW containing the Cs/Sr along with other fission products and lanthanides is vitrified and delay stored on site for up to 100 years.
- Hulls and ends will be disposed of as RH-TRU.
- Liquid radioactive discharges will be as near zero as practicable.
- Iodine 129, krypton 85 and carbon 14 removal incorporated.
- Design life of 40 years for LWR Recycle and MOX Facilities, 50 years for Waste Treatment Facilities and 100 years for HLW Product Store

LWR RECYCLING – NUEX SEPARATIONS



RE: Rare Earths
FP: Fission Products

Cost and Schedule Estimate- NFRC

.		Capacity	Capital Cost ($B)	Annual Operating Cost ($M)	Start Date
1	Initial LWR Recycling Center	1500 MT/yr	7.4	590	2023*
2	Initial MOX Fuel Fabrication Facility	200 MT/yr	4.0	161	2025
3	Waste Treatment Facilities	4500 MT/yr	5.2	416	2023
4	Am/Cm Target Fabrication Facility	1.5 MT/yr	0.6	45	2025

*Spent Fuel Cask Dry Storage Pad Facility incorporated to allow early receipt of SNF from Utilities, as soon as NRC COL License received (estimated to be 2015)

Nuclear Fuel Recycling Center - technology ready to deploy

TECHNOLOGY READINESS LEVEL LEGEND

AREA	NAME	TRL	COLOR
A	I-129 SEPARATION FROM DOG	6	
B	K-85 SEPARATION FROM DOG	5	
C	TRUEX	7	
D	TALSPEAK	5	
E	MAF	4	
F	AM/CM TARGET FABRICATION	6	
—	RECYCLING AND WASTE TREATMENT	9	
—	SUPPORT FACILITIES & STORES	—	

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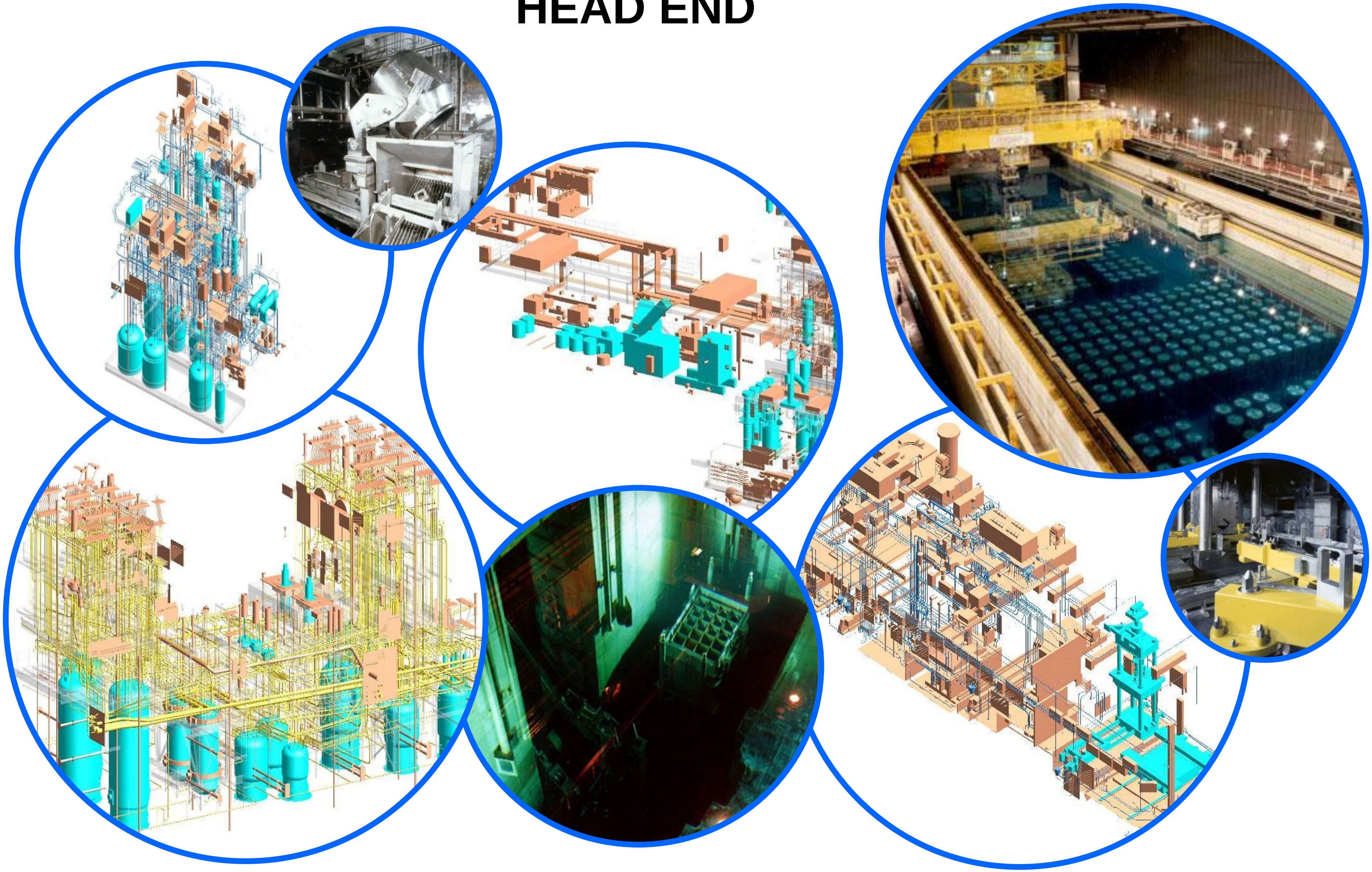
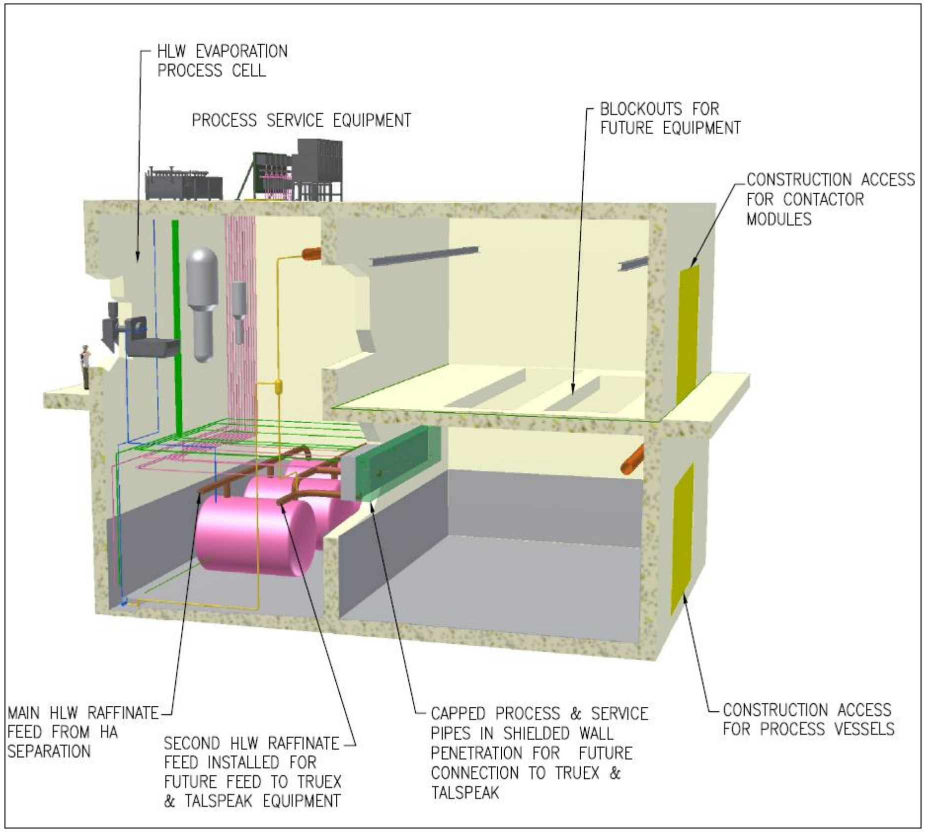
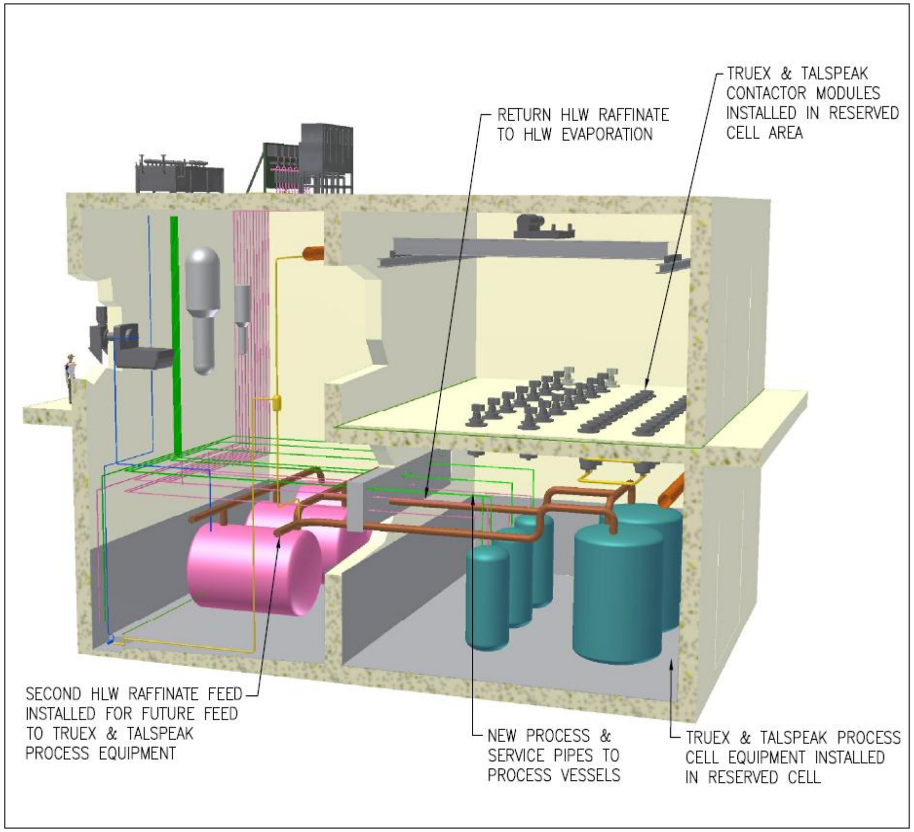
HEAD END



Flexibility of Design to allow future additions

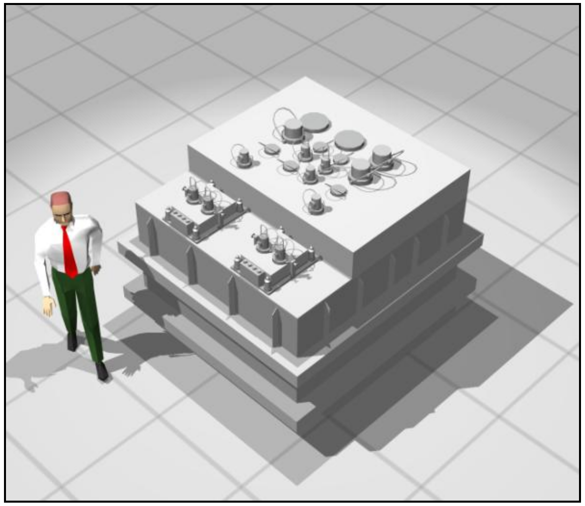
- Design and construction flexibility to allow for future installation of e.g., TRUEX and Talspeak process if decided to include later in the process:





Waste and Environmental impact

- Liquid Effluent
  - Existing commercial design is a near zero liquid discharge facility
  - Improvements identified through:
    - Evaporation
    - Ion Exchange systems
    - Liquid waste stream recycling for reagent make-up
    - All liquid wastes discharged will be compliant with federal and local regulatory requirements
- Aerial effluent
  - Includes technologies for I-129, C-14 and K-85 removal
- Solid waste
  - High level waste
    - Liquid waste evaporated prior to vitrification
    - Removal of Am/Cm from HA wastes to minimize long term radiotoxicity
    - Delay stored on site for up to 100 years prior to disposal to allow Cs/Sr decay
    - Intrinsically safe passively cooled HA product store



Waste and Environmental impact

- RH TRU or GTCC wastes
  - Primarily hulls and ends
  - Suitable for WIPP type repository with change in legislation
  - Volume minimized through compaction
  - Liquid slurries immobilized in grout
  - Suitable for disposal in existing transport containers (development of alternative to RH-72B recommended)
- CH TRU
  - Suitable for WIPP type repository with change in legislation
  - Provision of decontamination facility to minimize volumes generated
  - Supercompaction to reduce waste volume
- MLLW & LLW
  - Supercompaction to reduce waste volume
  - Sub-surface commercial disposal

GNEP Requirements for the Sodium Reactors

- Provide irradiation database for actinide bearing fuel
- Demonstrate actinide burning
- Be commercially competitive with advanced LWRs
- Urgency in deployment (Circa 2020)

Our Assessment

- Sodium Cooled Reactor technology is well documented and understood
- Our team is active in developing, testing and licensing an innovative sodium reactor design
- Overriding design requirements are: economic competitiveness, limited time and money available
- Our innovative approach is available today versus traditional gradual approach (distinct and successive test facility, demo, commercial prototype)

Our Focused Effort

- Concentrated efforts on an innovative design
- Initial focus on commercial function
- Core design: equilibrium cycles for commercial function, homogeneous core TRU fuel, one year refueling (0.8 CR)
- Plant design: driven by economics
  - Novel components where needed
  - Proven technology elsewhere

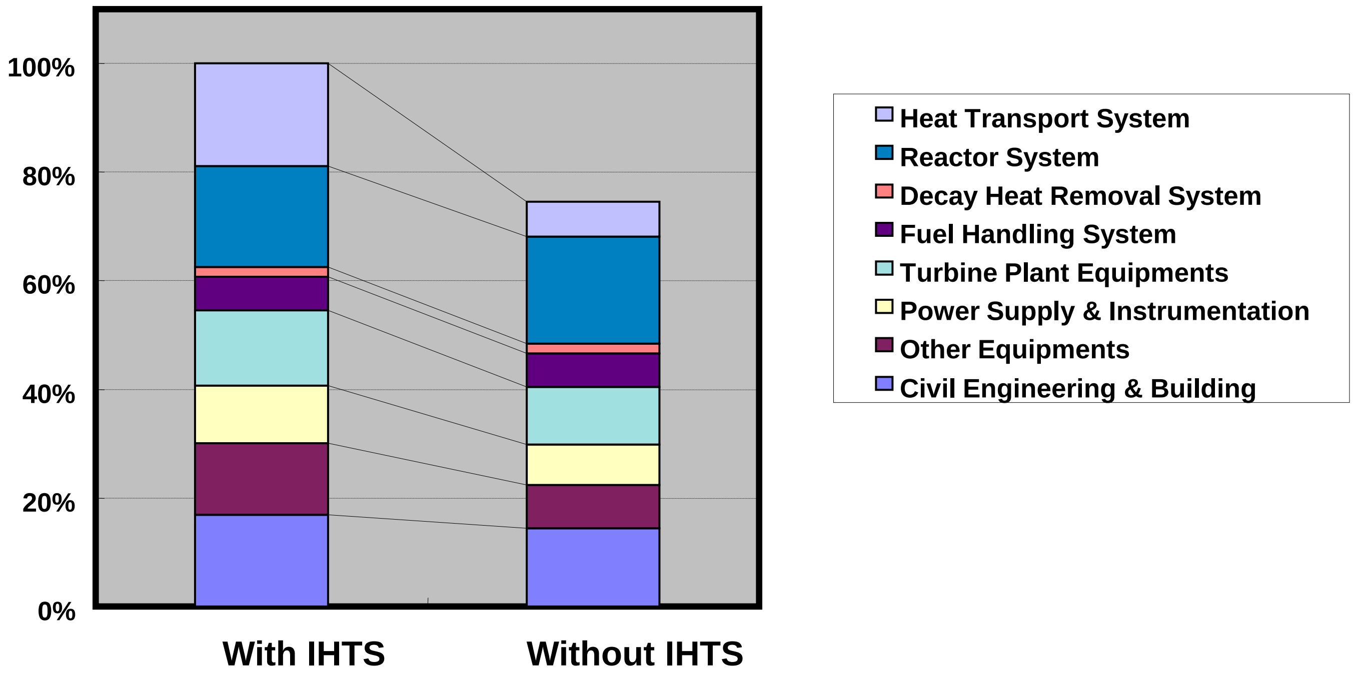
ARR Features to Drive Down Capital Cost

- Elimination of intermediate system
- Use of EM pumps
- Only one, simple auxiliary decay heat removal system
- ATWS cold shutdown
- Seismic isolators
- Other minor improvements

<u>Target</u>

At least one-third reduction versus “traditional” LMRs

Cost Reduction by Elimination of Intermediate Heat Transport System



25% cost reduction is expected by eliminating intermediate heat transport system.

Cost and schedule estimate – NFRC & ARR

.		Capacity*	Capital Cost ($B)	Annual Operating Cost ($M)	Start Date
1	Initial LWR Recycling Facility	1500 MT/yr	7.4	590	2023
2	Initial MOX Fuel Fabrication Facility	200 MT/yr	4.0	161	2025
3	Waste Treatment Facilities	4500 MT/yr	5.2	416	2023
4	Am/Cm Target Fabrication Facility	1.5 MT/yr	0.6	45	2025
5	First-of-a-kind (FOAK) Advanced Recycle Reactor (ARR)	410 MW(e)	4.4	57	2026
6	ARR Fuel Recycling and Fabrication Facility	20 MT/yr	1.2	46	2022
7	N^{th} -of-a-kind (NOAK) ARR (4-unit module)	1650 MW(e)	7.5	267	2033

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Closing the fuel cycle – technology & commercial deployment –LWR recycling

- Commercially proven, advanced technology is available & ready to deploy now for LWR recycling.
  - Separations
  - MOX fuel fabrication
  - Waste Treatment
- Am/Cm presents challenges but excellent concepts have been presented & should be developed; economics will decide
- The technology is proliferation resistant and pure plutonium is never separated nor produced.
- Facility designs meet all safety and environmental requirements.
- Recycling used LWR fuel makes economic sense now and reduces HLW volumes substantially.
- Can process all commercial SNF.
- No HLW requiring disposal for at least 100 years, no orphan waste.

Closing the fuel cycle – technology & commercial deployment – ARRs and transuranic fuel

- Advanced Recycling Reactor technology not yet ready to deploy but viable conceptual designs produced.
- Several innovative concepts have been presented that will lower the cost of the burner reactor
  - Elimination of intermediate system
  - Use of EM pumps
  - Only one, simple auxiliary decay heat removal system
  - ATWS cold shutdown
  - Seismic isolators
- Toshiba developing and licensing a sodium cooled reactor which incorporates several of the above features
- Proven technology can be developed & enhanced for ARR fuel fabrication & recycling
- The aqua- electro-winning process provides an excellent bridge between LWR fuel and metal fuel processing
- Focused technology development for ARR and its fuel processing should enable full commercial deployment in 35-40 years.

Closing the fuel cycle – economics and the business requirements

- Recycling spent LWR fuel is commercially viable & can be done now.
- First separations & mox facilities on line by 2023 at a cost of $16.6Bn.
- Based on public-private partnership, not a huge Government project, no need for huge appropriations.
- Recycle, recovery & re use of materials makes sense.
- Requires legislative & regulatory changes.
- Create a federal waste corporation FEDCOR with responsibility & authority to manage nuclear fuel and wastes as a business enterprise.
- Primary source of funds will be nuclear industry generated through waste fees & revenues from sale of recycled uranium & MOX fuel.
- FEDCOR would manage waste fund but not need to use the existing $20Bn.
- FEDCOR would acquire all recycle facilities, preferably on non DOE sites to limit extraneous infrastructure costs & maintain focus on mission.
- Single regulatory regime with NRC, EPA & States; no DOE/DNFSB oversight. Regulated as commercial business enterprise.

Closing the fuel cycle- stakeholder acceptance

- Solves the nuclear waste problem.
- Significantly reduces amount and toxicity of high level nuclear waste.
- Reduces risk of proliferation, plutonium consumed and pure plutonium never produced.
- Improves US energy security, reduces dependence on foreign supplies.
- Recycling will be paid for by the nuclear industry not the government.
- Allows carbon emissions to be reduced.
- Closing the fuel cycle will enable the nuclear renaissance & create over 250,000 much needed US jobs – many in manufacturing.

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Nuclear Fuel Recycling Center - technology ready to deploy

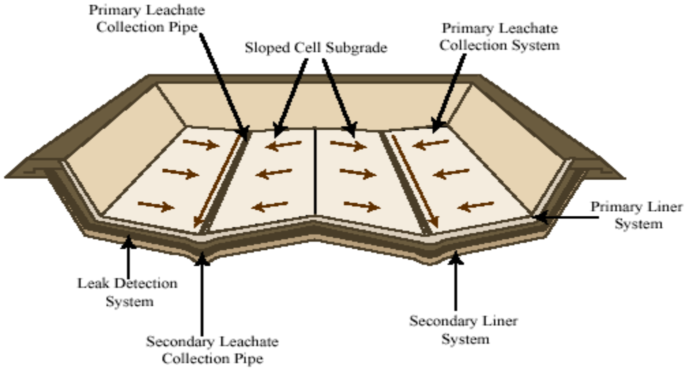
Proprietary Information

Summary of Development Work Required

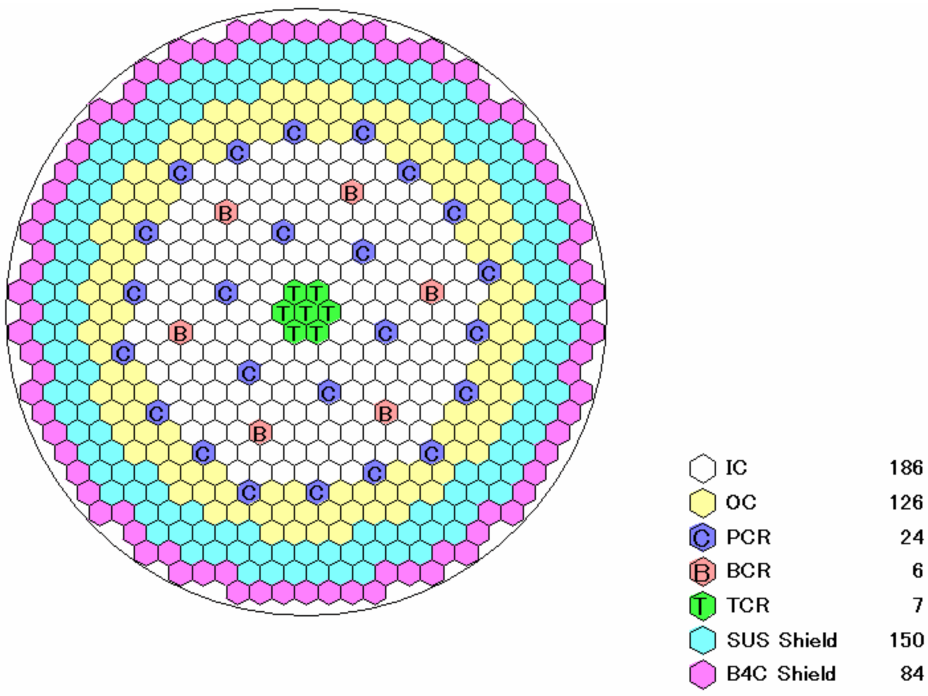
Technology Area	Work Description	Potential Collaborators	Comments
U sep'n from U/Pu/Np	Demonstration of AHA flowsheet	US or UK Nat Lab	Can be done as part of hot CETE testing
Tc-99 separation in UP	Demonstration of UP Tc removal flowsheet	US or UK Nat Lab	Can be done as part of hot CETE testing
TRUEX	Improvements to solvent loading	US Nat Lab	Separate development to optimize flowsheet, then CETE demonstration
TALSPEAK	Improvements to solvent loading, decreasing pH sensitivity	US Nat Lab	
Am/Cm Finishing	Proving of flowsheet	US or UK Nat Lab	Hot demonstration required
Tritium removal	Assessment work required	US or UK Nat Lab	May need hot demonstration
I-129 and Kr-85 removal	Demonstration of improved flowsheets	US or UK Nat Lab	Cold demonstration at pilot scale may suffice
Aqua-EW Process	Hot demonstration of oxalate precipitation and chlorination	US Nat Lab	Could be integrated into CETE testing
Electro-Winning	Scale-up development & testing	US Nat Lab	Range of unit processes need to be scaled up and demonstrated
MOX fuels with RU & Np	Need demonstration as test assemblies in reactors	US Nat Lab and/or utilities	Performance in reactors needs to be qualified
ARR Metal Fuel	Fuel qualification required	US Nat Lab and/or utilities	Performance in reactors needs to be qualified, esp. for MA fuels
RU Re-enrichment	All aspects of LIS development	US Nat Lab + commercial Labs	Development & demonstration with actual RU required
Am/Cm target fabrication	All aspects of target fabrication	US Nat Lab + commercial companies	Need to define preferred matrix and method of manufacture
ARR	All aspects of ARR	US Nat Labs + Utilities	Demonstration of aspects of core and reactor system design
CANDU Reactors	Am/Cm target performance	AECL + Canadian Utilities	Target performance and methods of loading

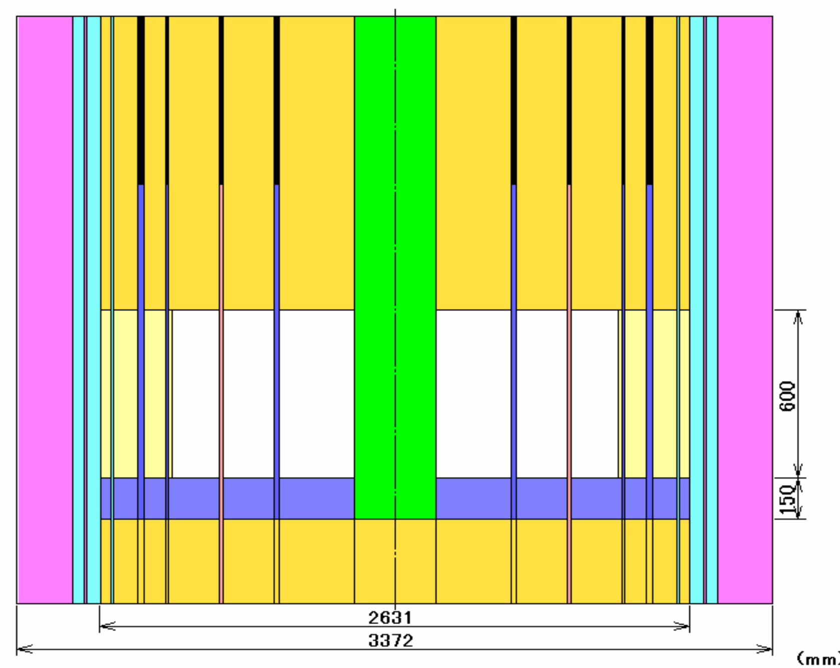
Decommissioning approach

- Risk to personnel, the environment, cost and schedule of D&D considered in the design and construction
  - Construction of major facilities will include a RCRA-compliant liner and leachate collection system allowing in place disposal after deactivation
  - Consideration of an expandable solid waste facility allowing size reduction of major items
- Decommissioning cost
  - $759 Million (2007 dollars)
  - Based on UK Decommissioning policy review costs for UK similar facilities.
  - Factored for in situ disposal of major facilities

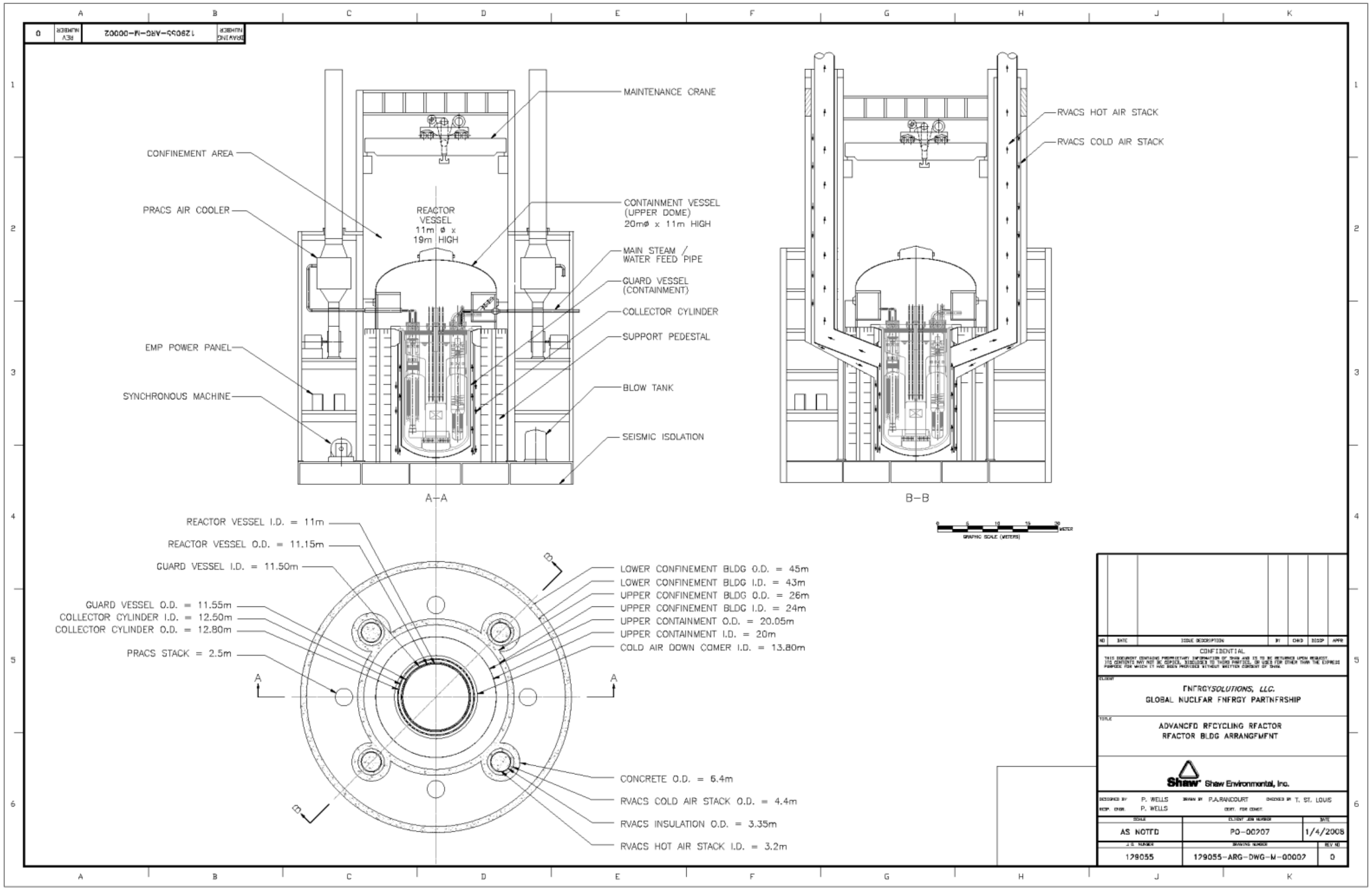


ARR Commercial Core Design





Advanced Recycling Reactor



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Proprietary Information

Next Phase

- Complete evaluation of cost reduction design modifications
- Optimize layout to minimize vessel/containment size and plant footprint
- Scope cores for testing and burner functions
- More detailed commercial core performance
- Establish metal and MOX fuel data base for licensing assessment
- Investigate increasing core burnup and extending refueling cycle
- Performing preliminary bottom-up cost estimate
- Outline licensing approach