Closing the Nuclear Fuel Cycle

Implications for Nuclear Waste Management and Disposal

September 23 2009

The Energy*Solutions* Team Perspective

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Introducing the team

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TOSHIBA

Shaw® Shaw Environmental, Inc.

Westinghouse

National Nuclear Laboratory

Booz | Allen | Hamilton

NFS

AECL

Why close the fuel cycle?

- Solves the nuclear waste disposal problem
  - Reduces amount, toxicity and heat of high level waste
  - Opens alternative repository options
  - Reduces need for multiple HLW repositories
  - Will lower future HLW disposal costs
- Provides additional waste confidence for nuclear new build to proceed
- Improves the security of US energy supplies
  - Recovers and recycles valuable nuclear materials

Our Approach

- Incremental approach to deployment of fuel cycle facilities
  - Near-term development of Generation III+ Commercial LWR fuel recycling– Industry and National Labs collaborate on focused development of a US design
  - Medium-term development of Generation IV Advanced Recycle Reactors and advanced fuel recycling - National Labs lead, Industry supports
  - Longer-term commercial deployment of Advanced Recycle Reactors

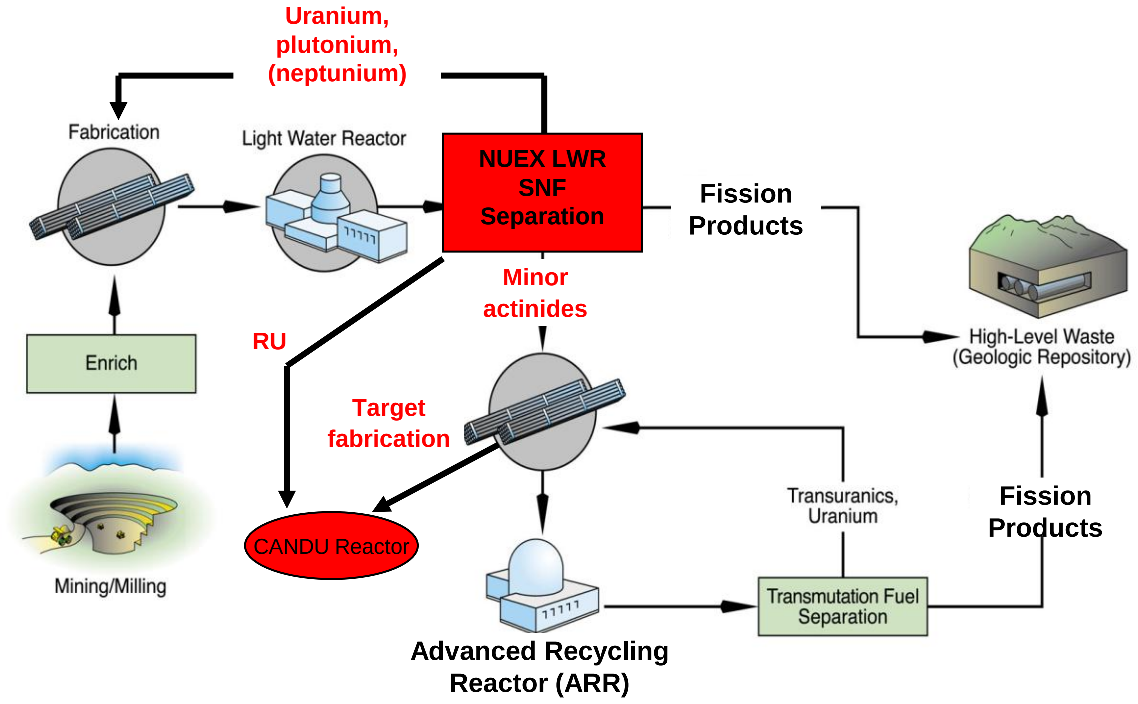
- Action needed now to be able to close the fuel cycle in the future
  - Develop legislative, regulatory and financial enablers
  - Establish New Government Entity to manage back-end fuel cycle
  - Undertake activities to support licensing requirements
  - Industry & National Labs work together on focused development needs
  - Select Site(s) for interim storage and fuel cycle facilities, based on volunteer states and communities
  - Study alternative nuclear waste repository options

Our Approach

- Use advanced, yet proven, processes and equipment for LWR recycling and product re-use (incorporate lessons learned from existing baseline processes)
  - Energy*Solutions* NUEX recycling process, 1,500 metric ton (MT) per year throughput facility, MOX fuel in existing LWRs, recycled uranium (RU) in existing CANDU reactors
  - Option for separation of Am/Cm for burning/transmutation in CANDU or LWR reactors
  - Mitigates technical and commercial risk by advancements to proven processes and equipment
  - Allows progress on used fuel disposition while awaiting transformational technologies

Our Approach

- Ability to re-use RU in CANDU reactors or existing/new build LWRs
- Ability to re-use U/Pu as MOX fuel in existing or new-build LWRs
- Ability, if required, to burn Am/Cm (as targets) in existing thermal (CANDU or LWR) reactors
- This approach “fills the gap” before Advanced Recycle Reactors enter commercial operation



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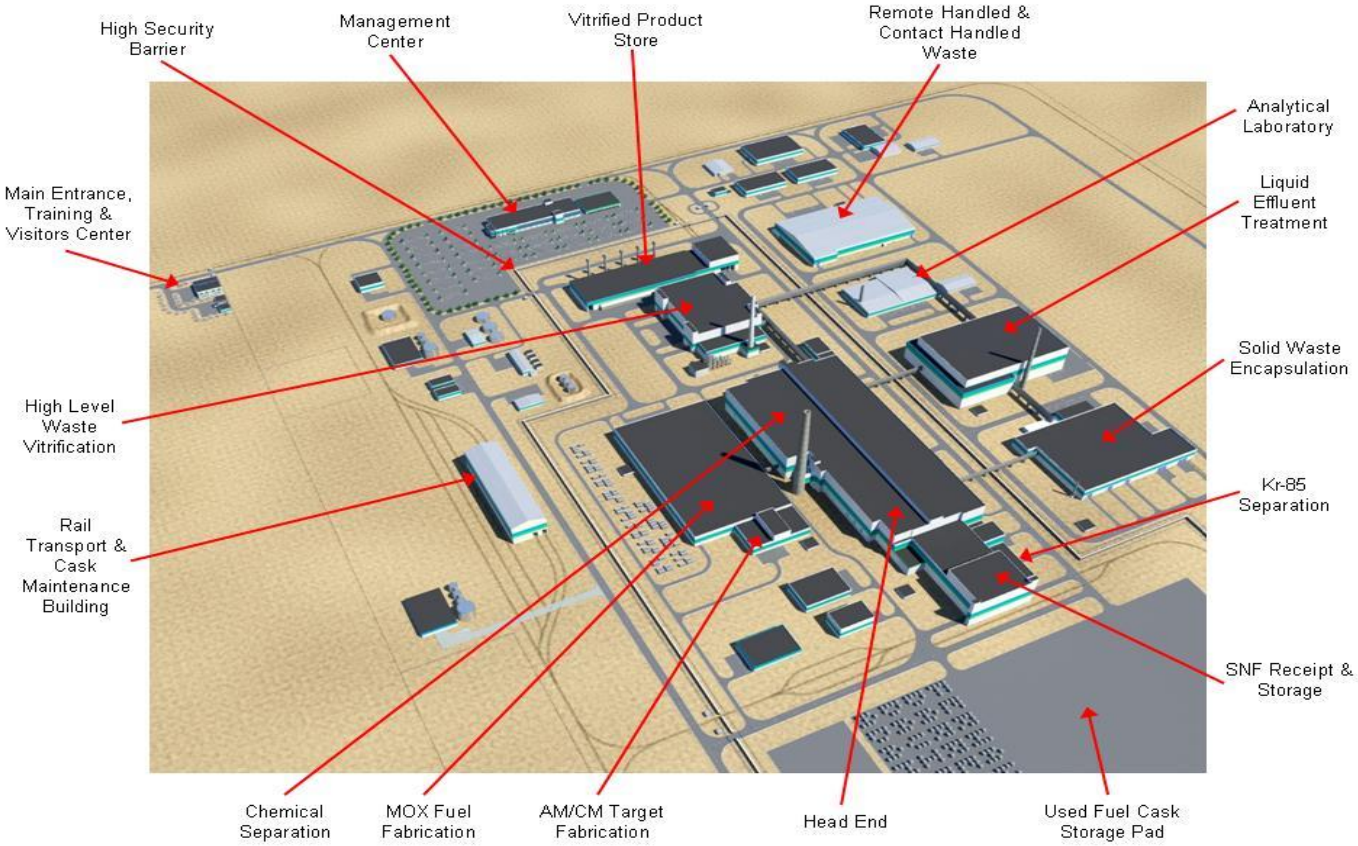
Our Facility

- Light Water Reactor Recycling Center situated on a 330 acre site



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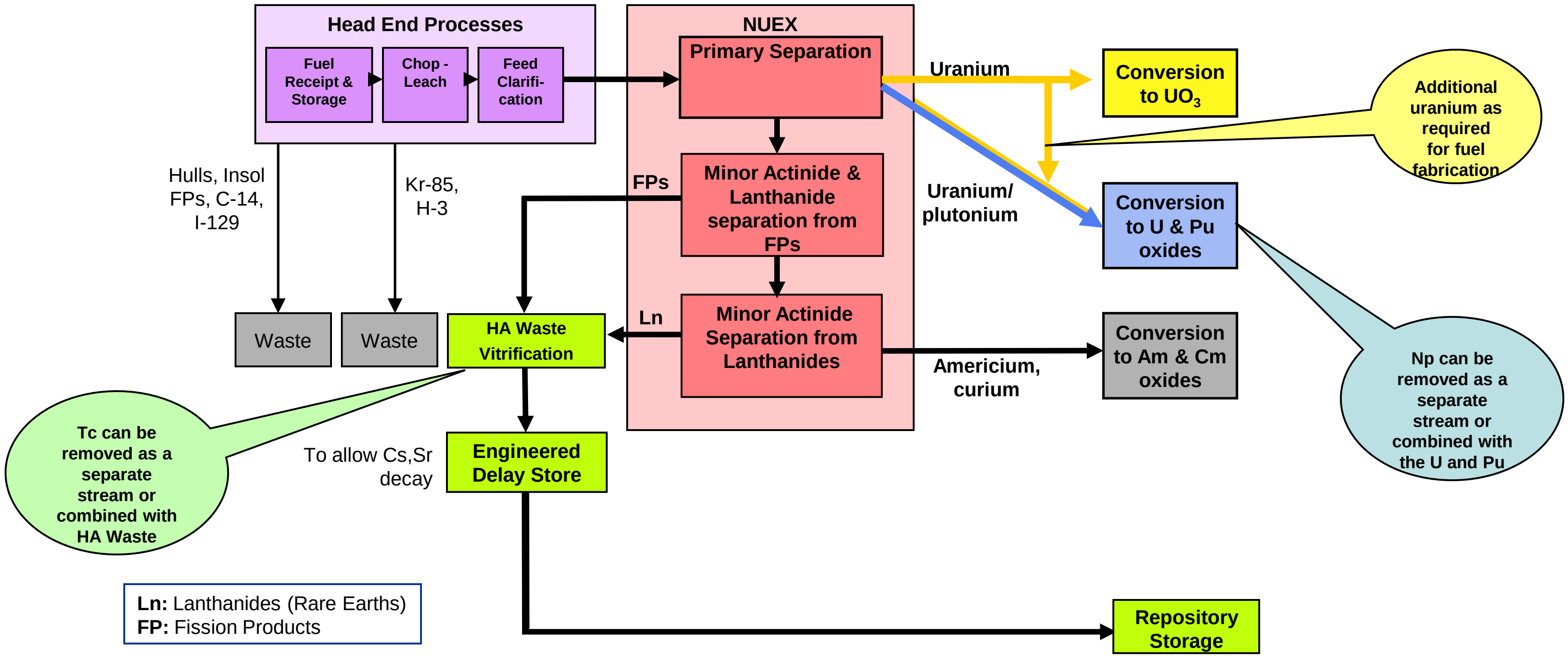
Our Separations Technology

- NUEX Flowsheet is designed specifically for advanced US recycling – major changes from current baseline flowsheet
- Equipment based on proven design, minimizes technical risk



Wastes from Recycling

- Recycling reduces the HLW volume for disposal by 75%
- Recycling produces GTCC waste that is about 35% of the original used fuel volume
- Recycling produces low level solid waste
- Recycling using the NUEX flowsheet predicted to result in
  - zero radioactive liquid discharges
  - near-zero aerial discharge

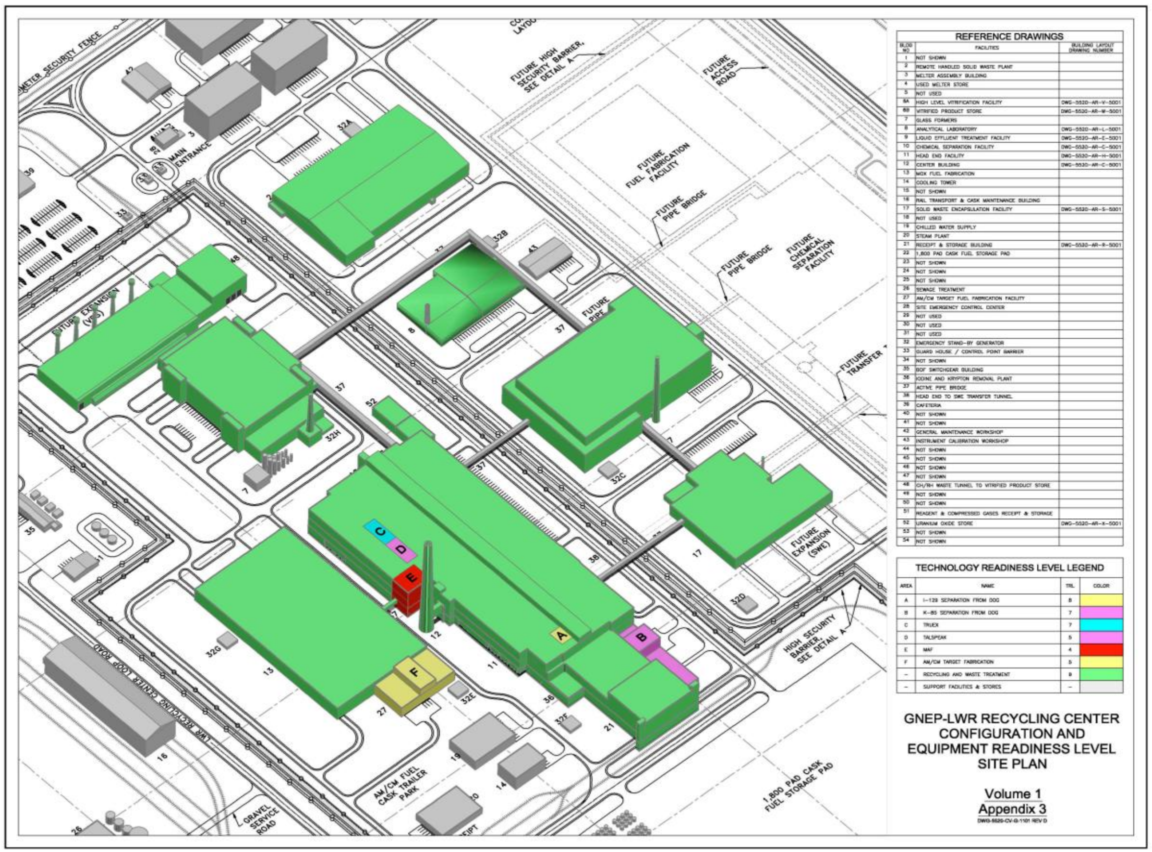
US NUEX recycling facility expected to have significant advancements in waste management compared to Sellafield, La Hague and Rokkasho

Wastes from Recycling

- Advances in Waste Management
  - High level waste incorporation rates into Glass reduces HLW volumes
    - Cs, Sr and Tc along with all other FPs incorporated into glass by advanced joule ceramic melters
  - Gaseous effluent treatment/capture (Kr, I, C-14) with goal of near-zero aerial discharge facility
    - Kr captured using cryogenic distillation, decay stored prior to discharge
    - I captured on silver mordenite media and disposed as solid waste
    - C-14 captured in barium carbonate and disposed as solid waste
  - Tritium treatment/Solidification of Liquid Effluents resulting in zero liquid discharge facility
    - Tritium in liquid effluents encapsulated in cement based matrix
  - Volume reduction of all Low level waste (GTCC and Class A/B/C)
    - Supercompaction

Our Advancement Approach

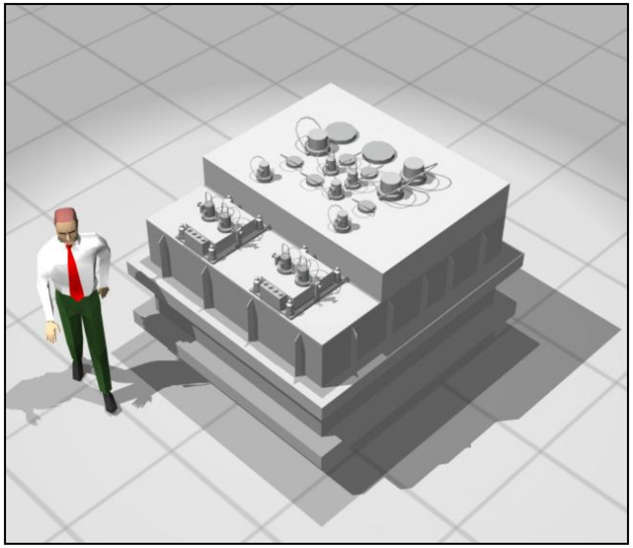
- Advancements in NUEX Flowsheet and Waste Management do not significantly affect size and complexity of facility



Wastes from Recycling

- Liquid Effluent
  - Baseline commercial design is already a near zero liquid discharge facility
  - Improvements identified through:
    - Evaporation
    - Ion Exchange systems
    - Liquid waste stream recycling for reagent make-up – excess (including tritiated water) is encapsulated
    - 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 heat load and 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



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Wastes from Recycling

- RH TRU or GTCC wastes
  - Primarily hulls and ends
  - Suitable for WIPP type repository with change in legislation
  - Volume minimized through compaction
  - 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

Wastes from Recycling

- The wastes produced from recycling the nuclear fuel that has provided the **annual electricity needs for over 250,000 family homes**

Radioactivity content 100%

10.9m^3

Cost to dispose $6 million

Radioactivity content 99%

0.8m^3

Cost to dispose $1.2million

Radioactivity content 0.9%

3.9m^3

Cost to dispose $0.5 million

Radioactivity content 0.1%

71m^3

Cost to dispose $0.1 million

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Wastes from Recycling

- Or to put it another way:
  - If all the electricity consumed by an average US household **over their lifetime** was generated by nuclear fuel, then the resulting wastes from recycling would be:

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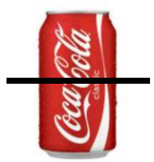

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Radioactivity content 99%	Radioactivity content 0.9%	Radioactivity content 0.1%
Half a Soda Can of Vitrified HLW Waste	Milk container of GTCC low level waste	Paint can of low level waste
7 fl oz	**0.25 gallons**	**5 gallons**

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Waste Streams

	Source	Volume m^3/yr	Mass Kg/MTIHM	Containers #/yr	Disposal Container	Disposal
High Level Waste	Highly active liquid waste	97	181	119	HLW canister	Geologic repository
Class C waste	Maintenance and clean up operations	113	60	282	100/55 gallon drums	Commercial disposal
Class A waste	Maintenance and clean up operations	1,335	764	3,602	100/55 gallon drums	Commercial disposal
	Grouted tritiated water plus C-14 slurry & salt concentrate	11,122	16,400	672	Half-height 20' cargo containers	Commercial disposal
	Pyrolized Solvent Ash	132	133	349	100 gallon drums	Commercial disposal
	Spent Ion Exchange Resin	11	7	2.1	210-Liners	Commercial disposal
Contact Handled TRU waste	Maintenance and clean up operations	130	69	326	100/55 gallon drums	Salt repository
Remote Handled TRU and GTCC waste	Fuel assembly hulls and ends plus I-129 waste	371	639	419	RH-72B	Salt repository
Kr 85	Dissolver Off-gas	3	N/A	103	Gas bottles	Decay storage and discharge

Throughput and Lessons Learned Assessment

- Operational Research (OR) Model used to analyze baseline commercial design to identify major bottlenecks and incorporate design solutions
  - Fuel handling
    - 2 fuel removal machines instead of one
  - BWR fuel handling
    - Handling of multiple assemblies for concurrent shearing
  - Dissolver acid heat up times
    - Pre heat of dissolver acid
  - Fuel campaigning
    - Campaigning assumed not required
  - Use of Reliability Centered Maintenance processes to maximize operability of key equipment and identify preventative maintenance regimes.
- The model assumes a realistic 2 month outage annually, plus reliability/availability data from UK operational facilities
- Significant experience in increasing production on 2nd and 3rd generation facilities
  - AMWTP versus WTC supercompaction throughput increased sixfold using similar equipment
  - Sellafield 3rd vitrification line versus lines 1&2 throughput increased twofold

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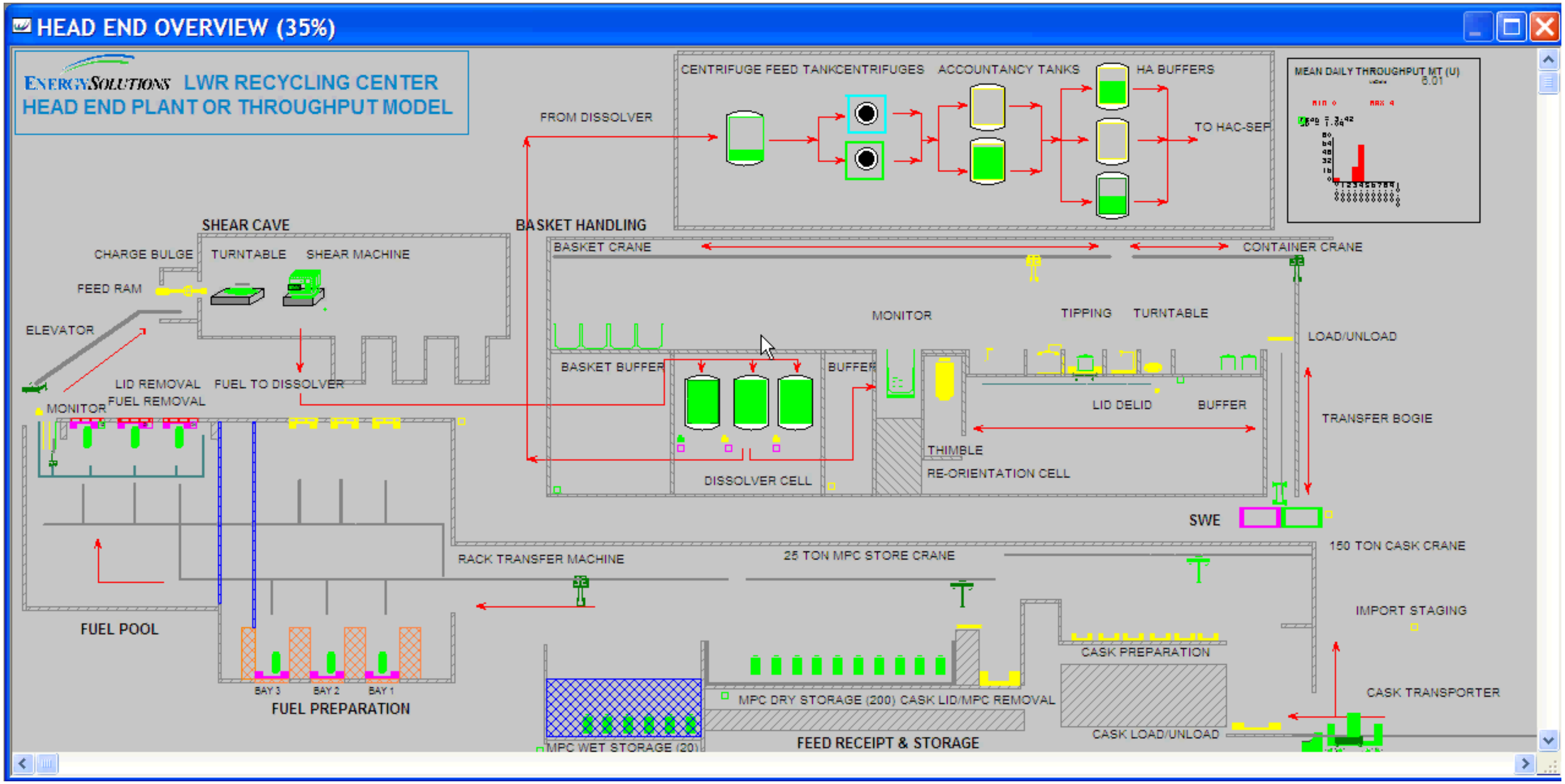
OR model dynamic simulation



Closing the Fuel Cycle- Conclusions

- Closing the fuel cycle will:
  - Solve the nuclear waste problem
  - Significantly reduce amount, heat load and toxicity of high level nuclear waste
  - Minimize risk of proliferation, plutonium is consumed and pure plutonium never produced
  - Improve US energy security, reduce dependence on foreign energy supplies
- Recycling will be paid for by the nuclear industry not the government
- Allows carbon emissions to be reduced by supporting the nuclear renaissance
- Create thousands of much needed US jobs – many in manufacturing and construction