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Waste Generated from Recycling of Used Nuclear Fuel

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U.S. NUCLEAR WASTE TECHNICAL REVIEW BOARD MEETING

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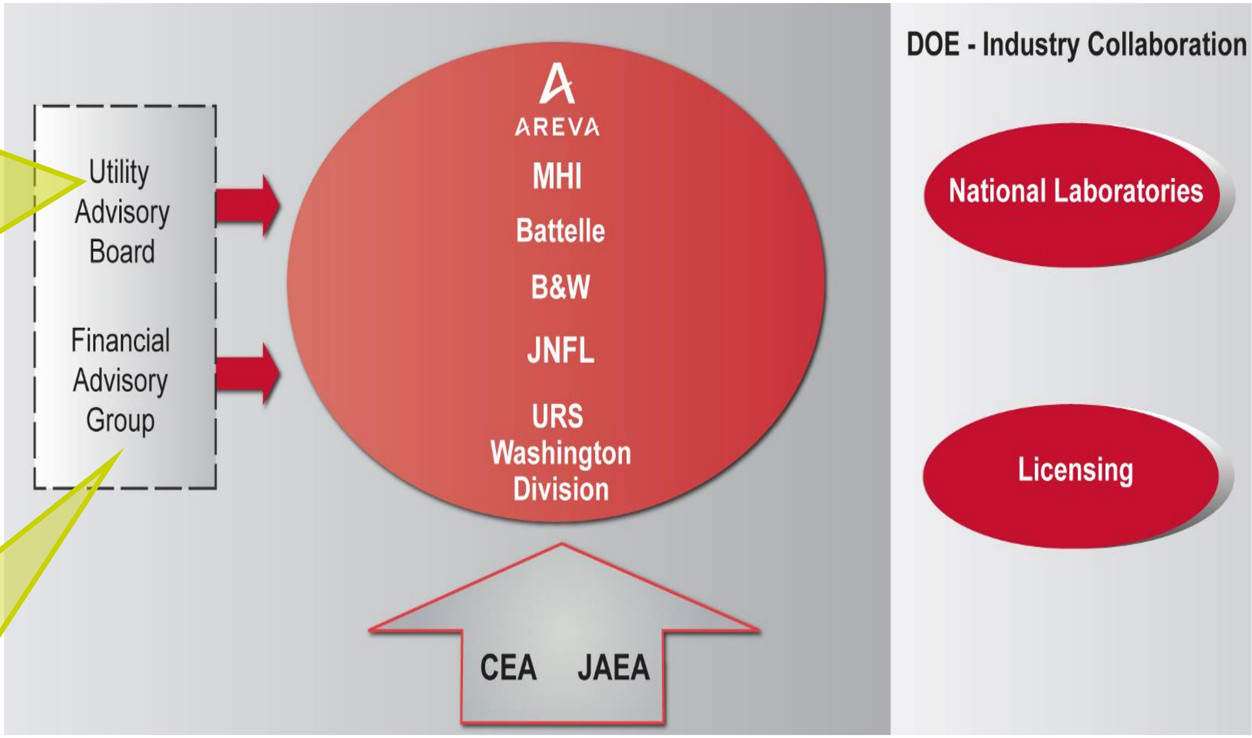
International Nuclear Recycling Alliance (INRA)

Should U.S. consider recycling?

- Recycling makes sense, especially if it can be financed through the NWF
- Responsibility for an integrated nuclear waste management strategy for the U.S. should be transferred to a new government entity

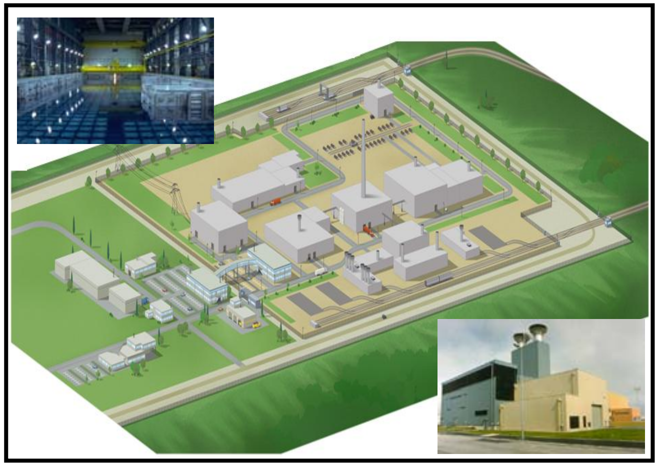
What is required for private financing?

- Commercial model with existing fleet (e.g., LWR recycling)
- Investment grade with guarantees (e.g., proven technology)
- Rulemaking (one-step licensing)



Study Results based on Technology Readiness and Business Plan

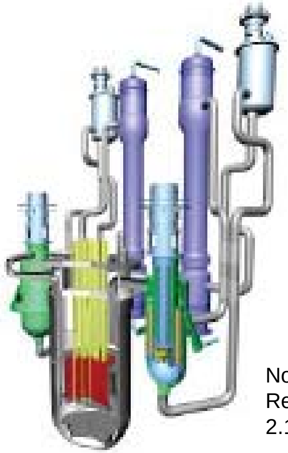
Consolidated Recycling Facility (CRF)



Commercially available

- Based on state-of-the-art, proven (50 years) technology/experience La Hague/Melox, Rokkasho, Thorp
  - COEX™ process - no pure plutonium stream
- Co-location of separation and fuel fabrication
- Capacity based on market for recycled fuel
- Flexible to allow deployment of new technology

Sodium Fast Reactor (SFR)

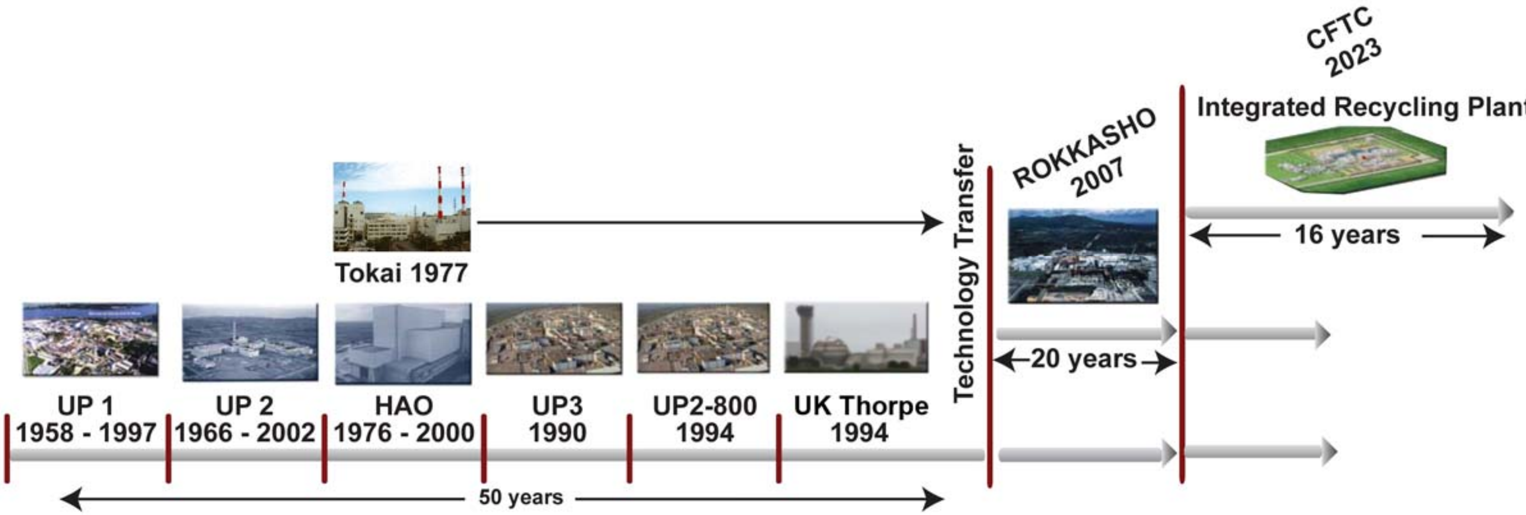


Note: Adapted from "JAEA-Research 2006-042", Fig 2.1.1-4, p. 69 (2006)

Commercial Demo Required

- Existing roadmap for commercializing fast reactors in Japan provides a solid foundation
  - Based on technology/experience from JOYO, MONJU, Phenix, SuperPhenix
  - R&D required to make commercial design cost-competitive and enhance reliability and safety
- Start with oxide fuel but can burn metal fuel
- Homogeneous or target transmutation fuel

Recycling Experience



- **Pre-conceptual design of the initial US Facility based on proven state-of-the-art processes and technologies from France, UK and Japan (50 years of commercial experience and continuous improvements)**
  - **to mitigate the risks (schedule, costs, licensing, safety)**
  - **to guarantee process efficiency and technology reliability**
  - **to minimize the impact on the environment**
  - **to allow flexibility (evolutions of the plant during operation)**

Assumptions for Closed Fuel Recycling Studies

- **Technical**
  - **Geological Repository - Yucca Mountain**
  - **Reference fuel: PWR fuel – 50 GWd/t – 4 years cooling time for maximum benefit to repository (reduced Am, therefore, Np content)**
  - **Treatment of UNF of any burn-up (UOx and MOX) from LWR possible**
  - **No pure Pu stream and mature technologies to reduce risk**
  - **Fabrication of LWR and SFR MOX fuels**
  - **Advanced processes to be implemented when mature, working with National Labs to develop and implement**
- **Business**
  - **Commercial facility**

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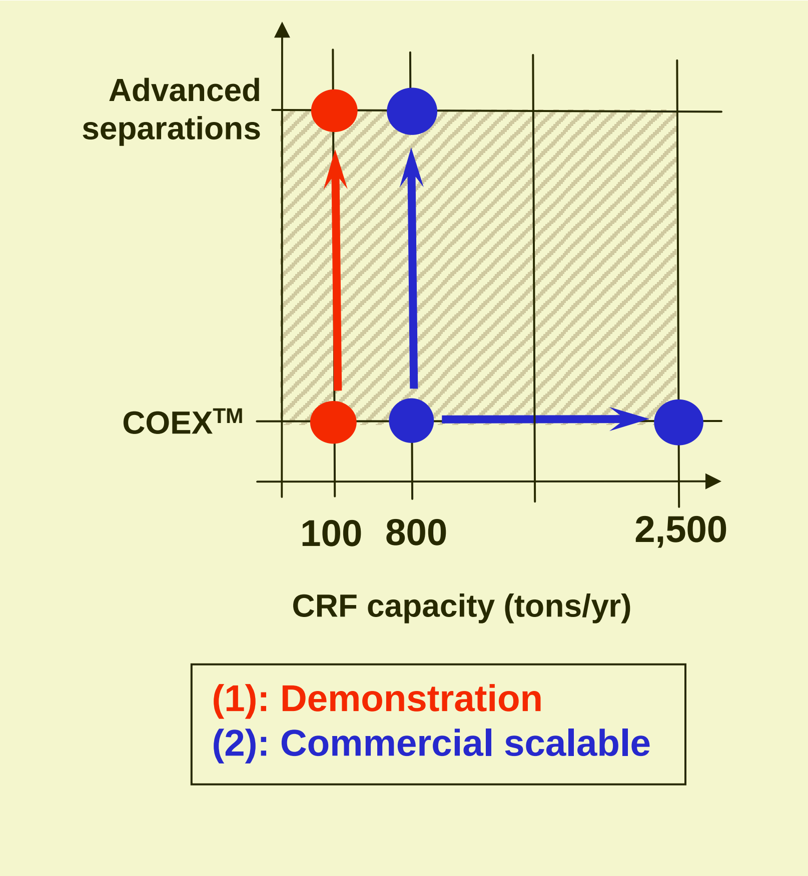
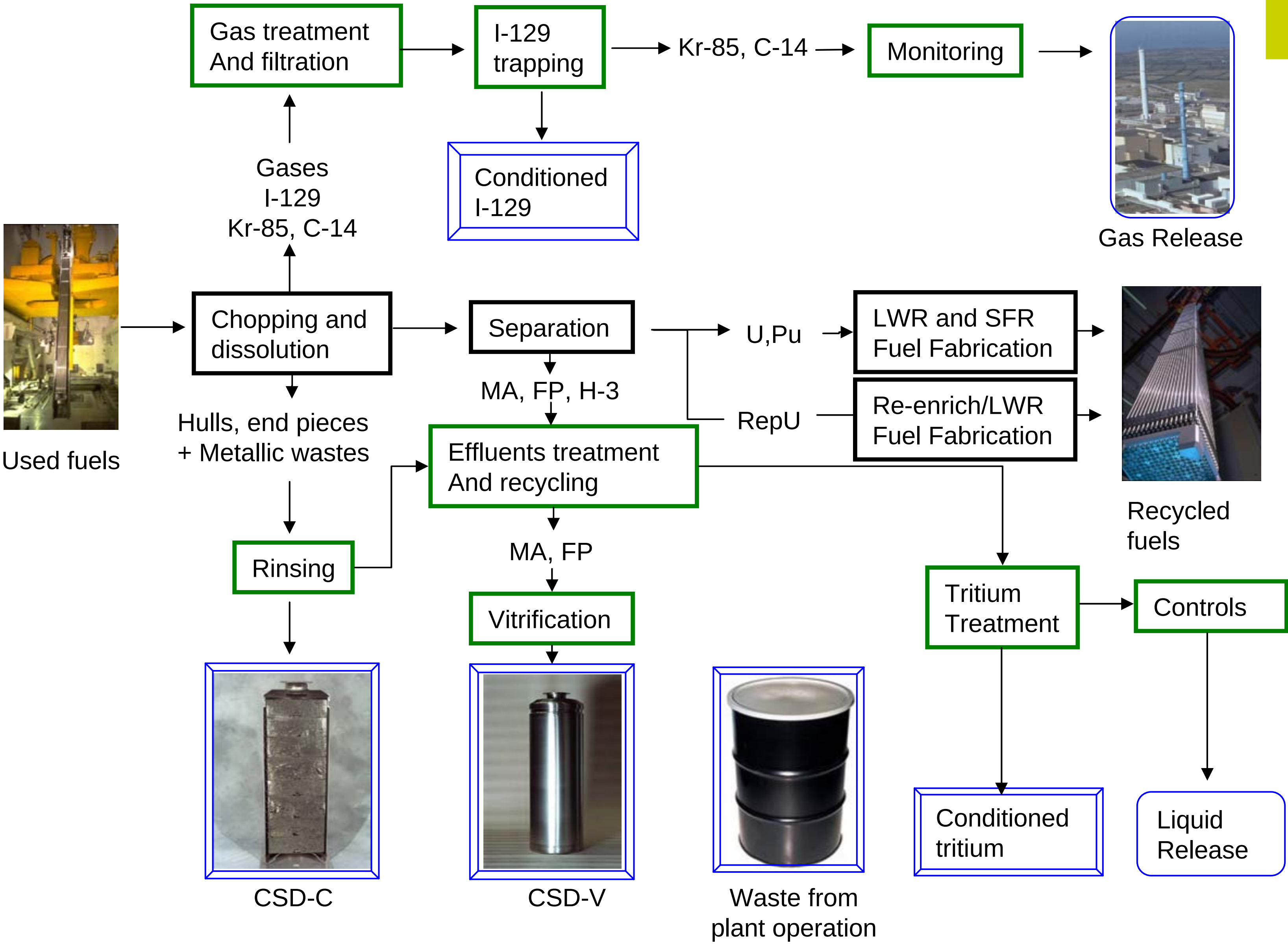
Recycling Scenarios

- **Commercial Scalable Reference Design**
  - **COEX™ process**
  - **Any burn-up/age UNF**
  - **FP and MA in glass**
  - **LWR and SFR fuel fabrication**
- **Evolutions**
  - **Capacity increase (800 to 2,500 Mt/y)**
  - **Advanced MA separation when mature**
  - **Transmutation fuel fabrication**
    - **Homogeneous / heterogeneous**



Process Diagram for CRF



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Solid Waste From Recycling

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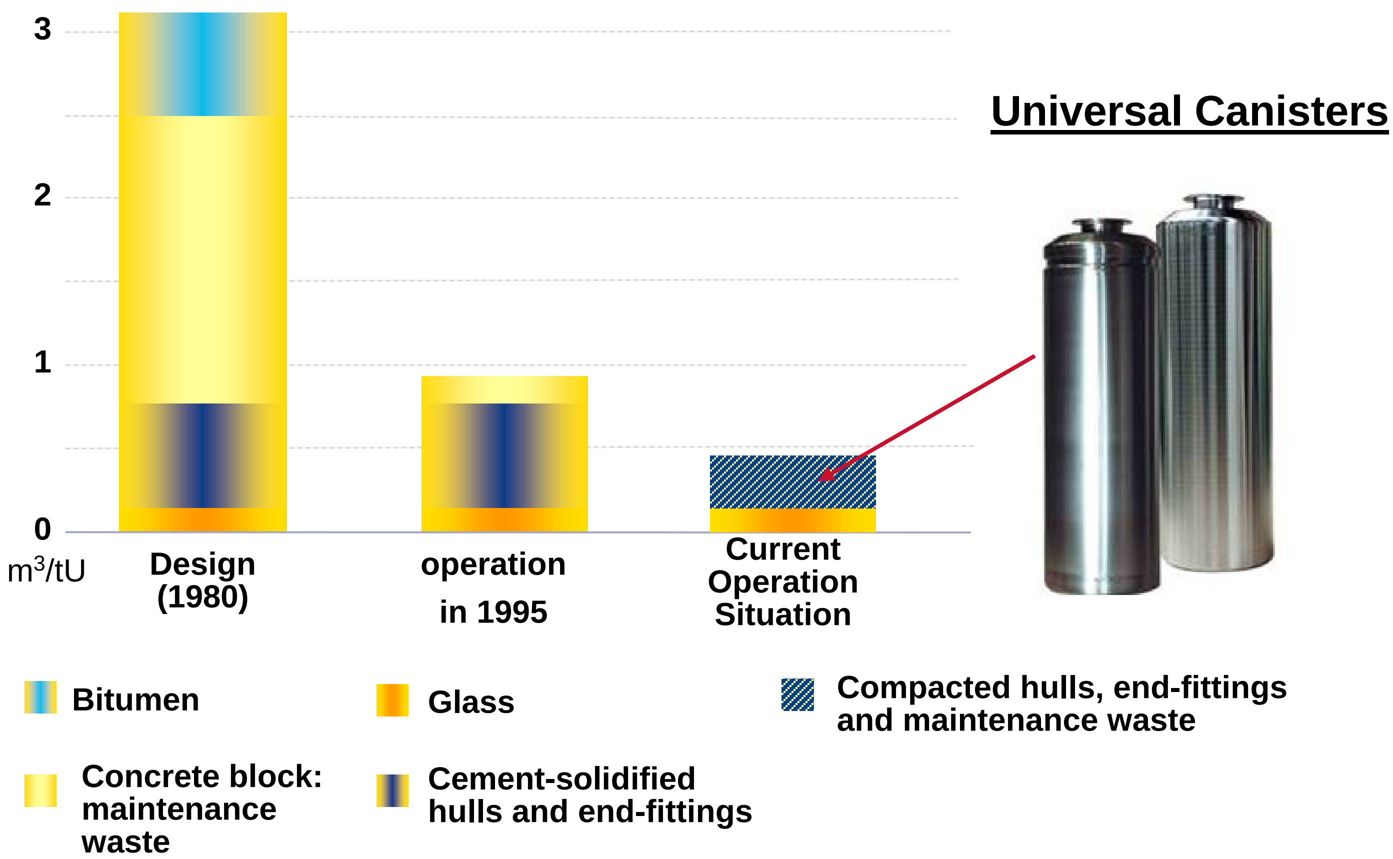
Continuous Volume Reduction Over Time
Operational Experience from France



Facility operational feedback, combined with ongoing R&D programs have resulted in a reduction of HLW volume generated by a factor >5 in operational facilities

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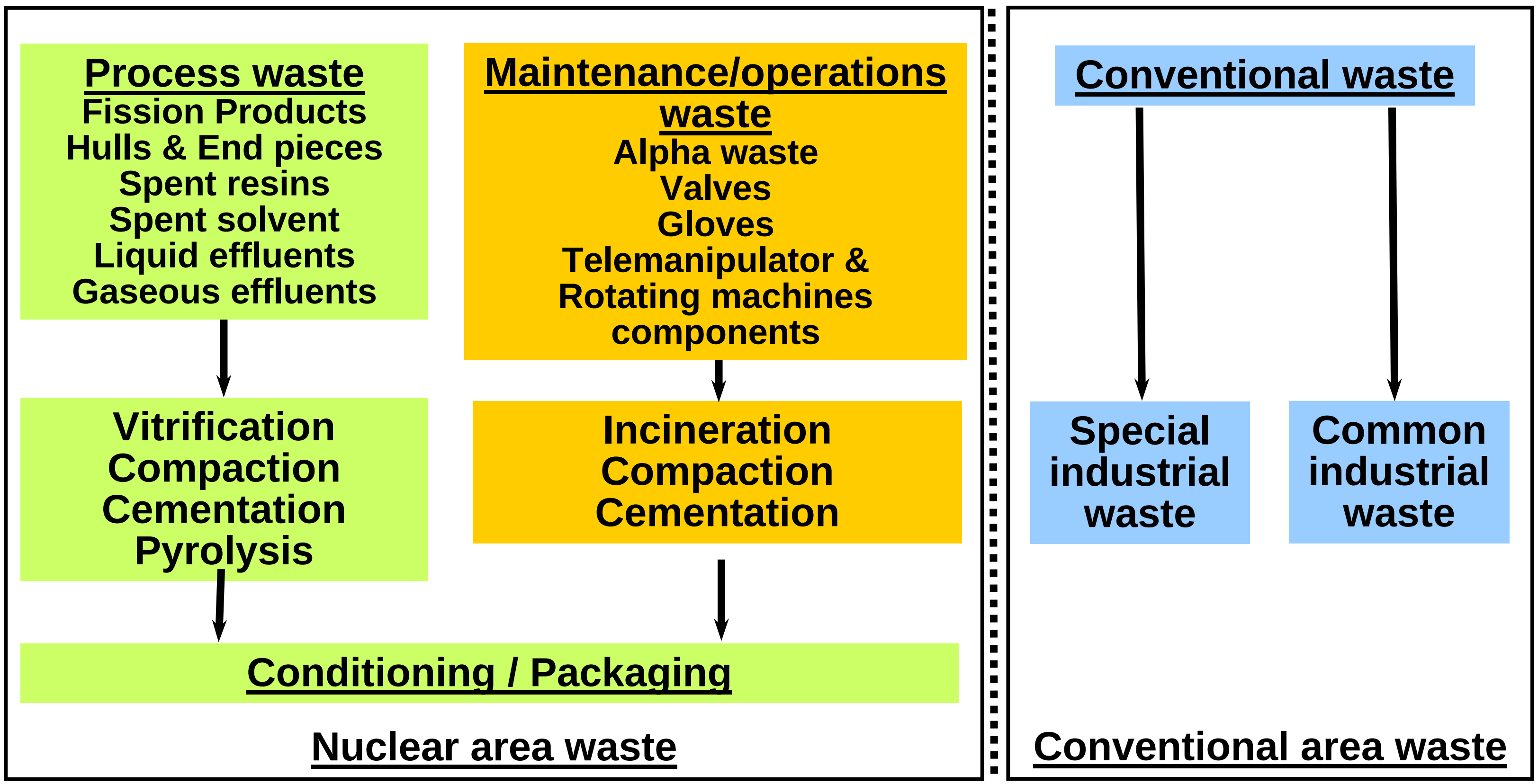
Waste Management Overview

- **Main categories of waste from recycling plants**
  - **Conventional waste (non nuclear waste)**
  - **Nuclear waste**
    - Maintenance waste, arising from plant operation
    - Process waste, produced as part of the recycling process itself



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Waste Management Principles

- Main objective is to ensure the final conditioning of every waste stream with robust waste forms and defined disposal paths
- Goal is to reduce the quantity and the radiotoxicity of the final waste to be disposed of (especially in deep geological repository)
- Main principles for limiting waste volumes
  - Untreated Waste Minimization:
    - Design and performance of the recycling plant
      - Modular equipment
      - High equipment reliability
      - Maintain equipment as long as possible (decontamination and repair)
    - Sorting at the source of the waste and classification of the waste according to activity level
  - Application of most suitable treatment process
    - Vitrification, Compaction, Cementation, …
  - Recycle liquid streams where possible

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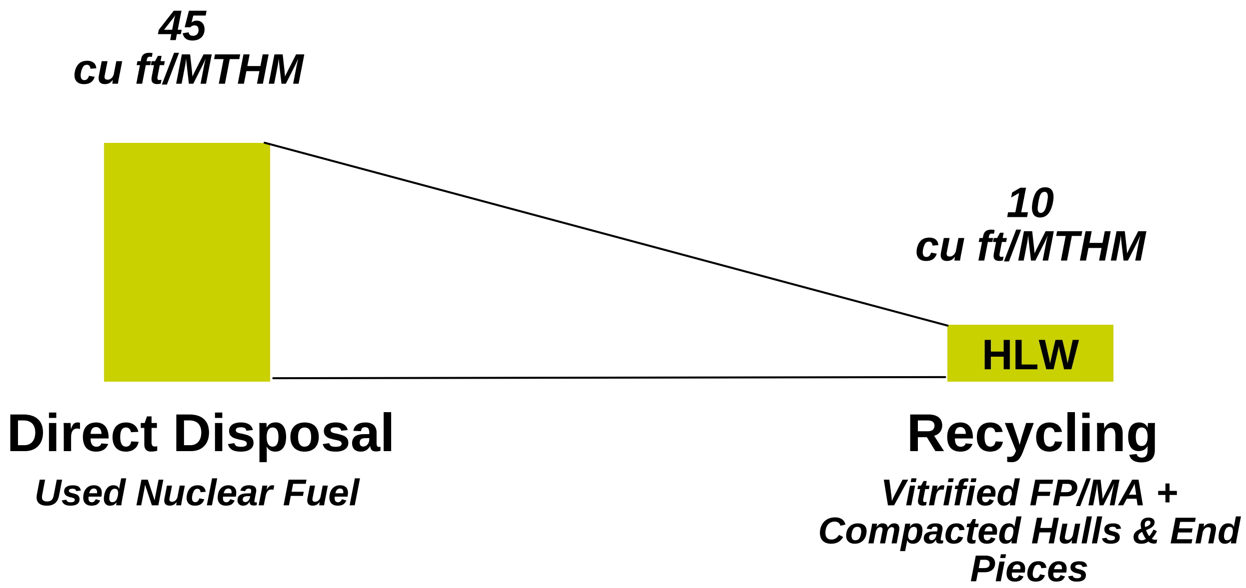
Waste Volumes from Recycling: HLW



Recycling option:
At least 4 times less space needed
for deep underground disposal

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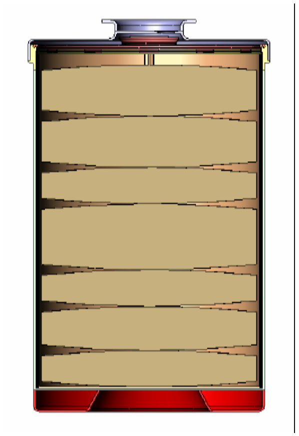
Solid Waste Volumes from Recycling

Deep Repository (HLW/GTCC)

<100



Alpha Waste

15

HIC Cemented

560

Vitrified FP and MA

560

Compacted Hulls and End Pieces

10 cu ft/MTHM

*Based on 800 MT/y recycling facility

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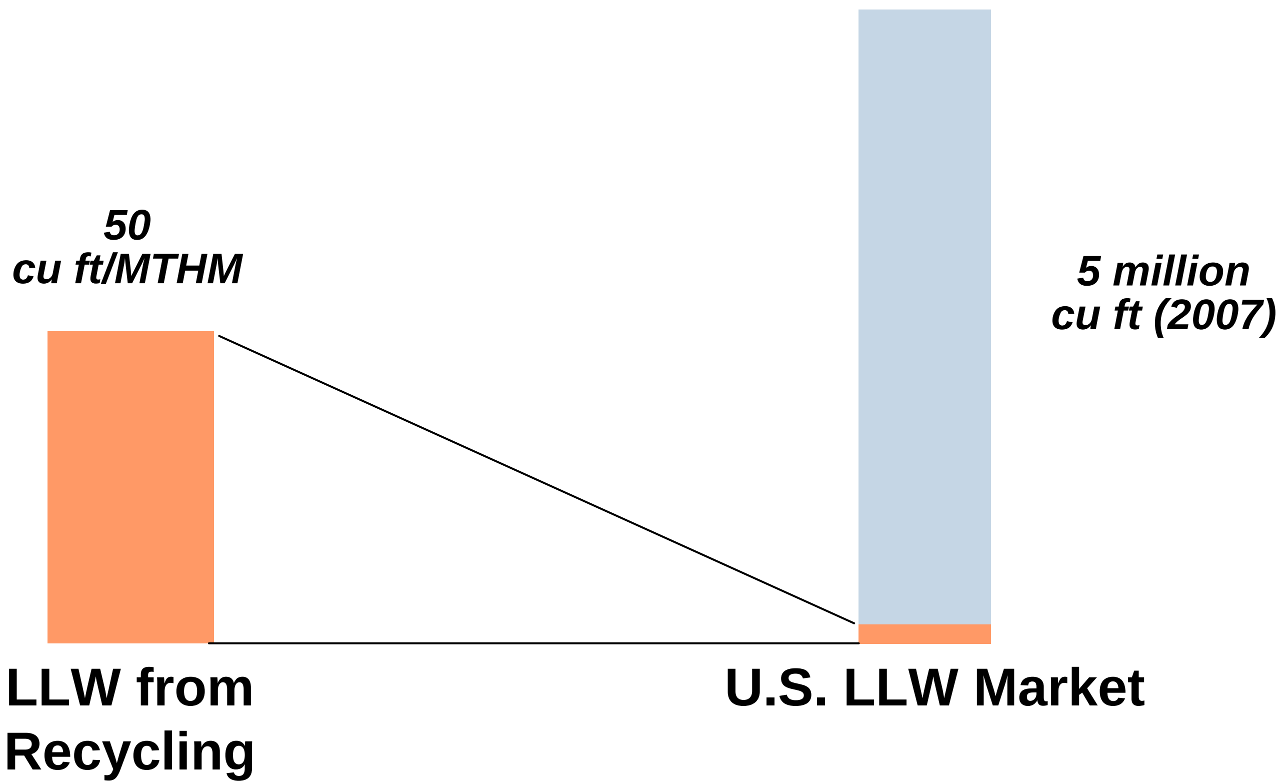
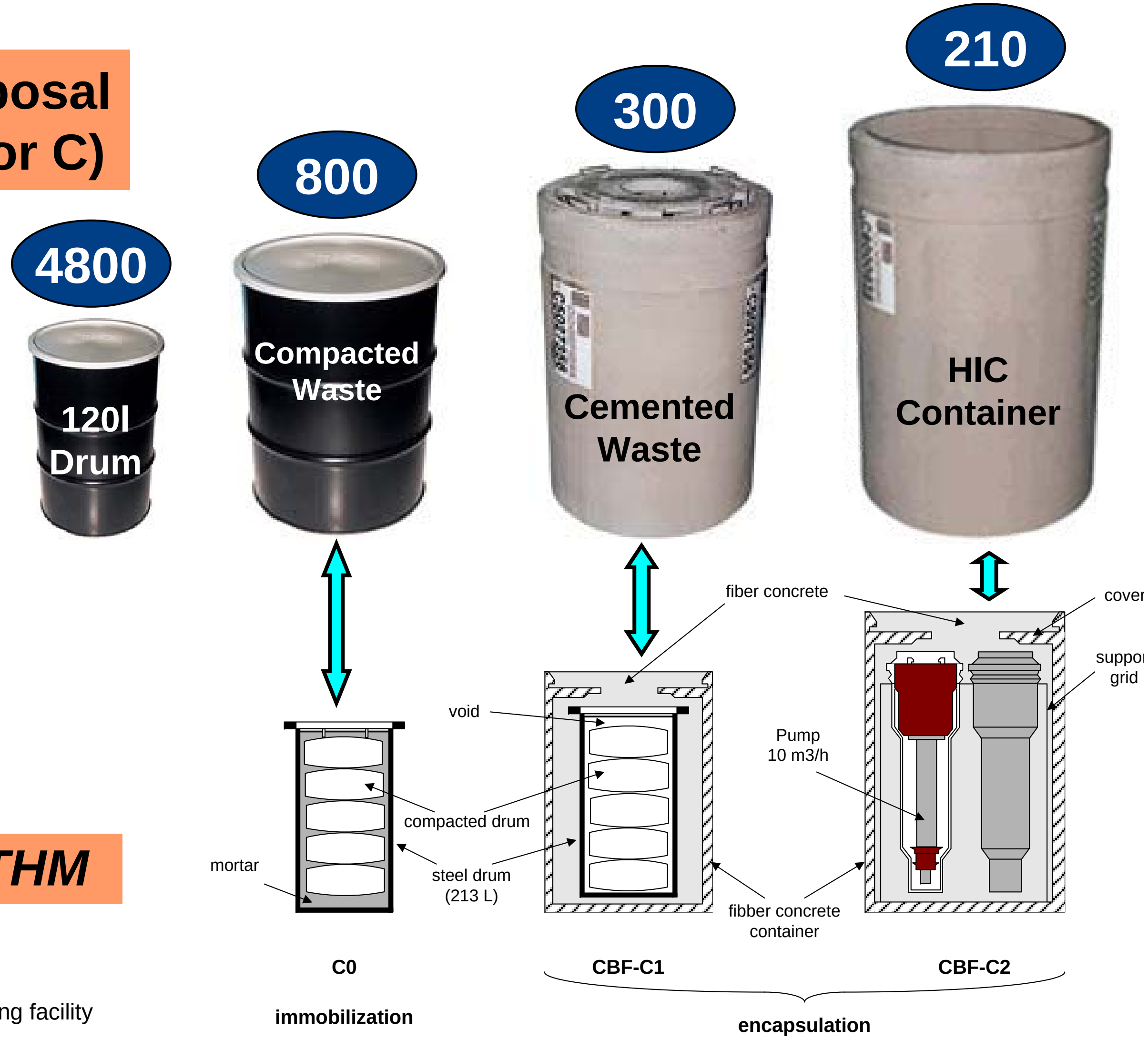
Waste Volumes from Recycling: LLW



Recycling of 2,500 MTHM generates approx. 2% of US Market

Solid Waste Volumes from Recycling

Surface Disposal (Class A, B or C)



50 cu ft/MTHM

*Based on 800 MT/y recycling facility

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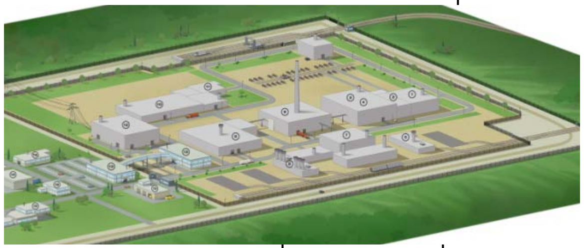
Solid Waste Disposition



Consolidated Recycling Facility

Vitrified Glass / Compacted Waste Canisters		**HLW Geological Repository**
TRU Waste		**DOE Disposal Site (WIPP)** **NRC-licensed Disposal Site**
Mixed LLW Iodine Traps	Waste Treatment R&D (trace amounts)	**TBD (based on classification**
LLW Wastes Process Job Control/Equipment		**DOE or Commercial LLW Disposal Site**

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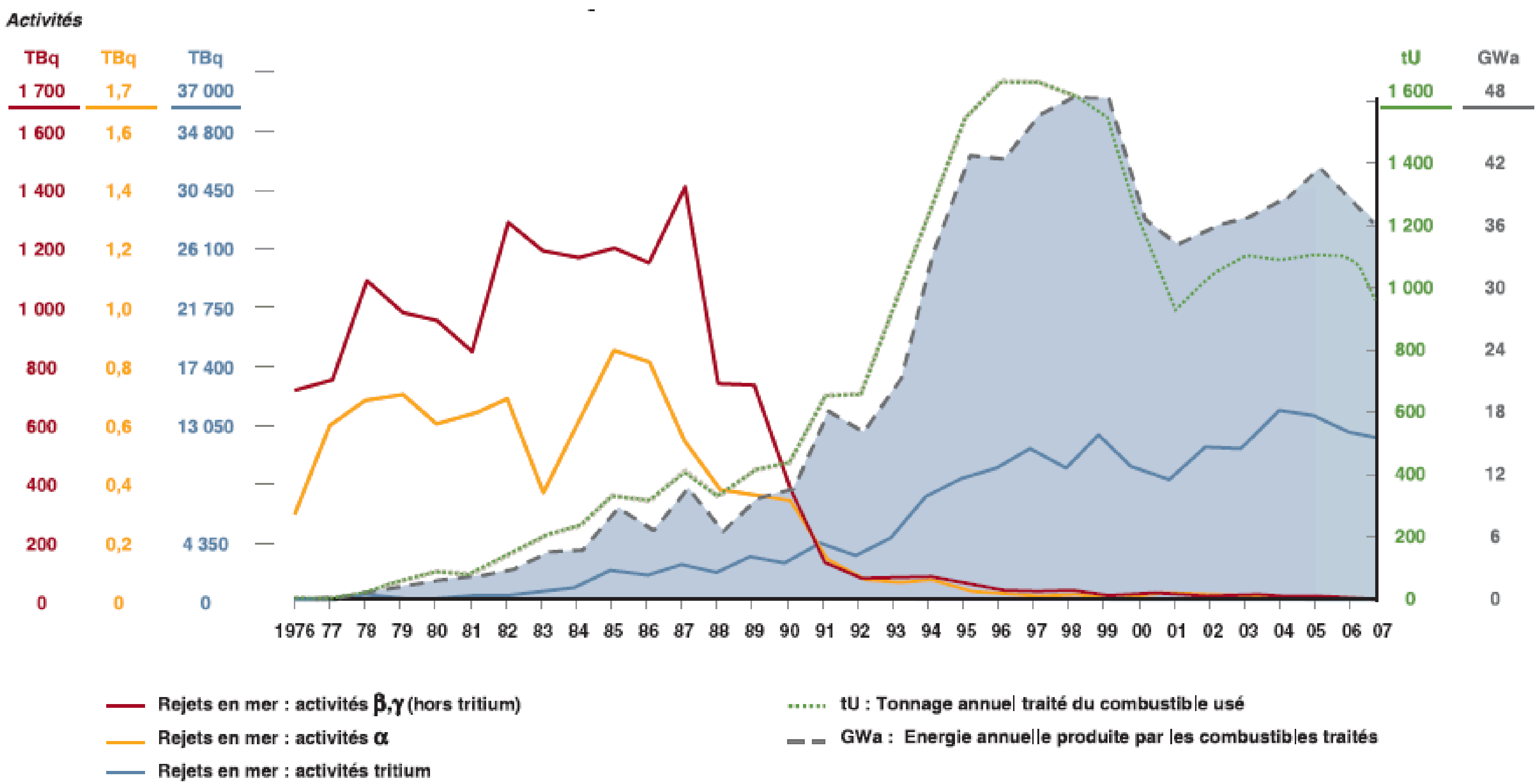
Gases / Liquids

Culture of Continuous Improvement

- **AREVA adopts a corporate policy of continuous improvement, as such new technology is continuously being developed, industrialized and deployed to improve plant performance, reduce waste volumes and increase plant safety**



Projected Releases from Recycling: Dose Impact and Regulatory Considerations

- **Projected releases from facility well below dose limits in 40CFR190.10a**

	EPA Limit (mrem/yr)	Air (mrem/yr)	Liquid (mrem/yr)	Total (mrem/yr)
Whole Body	25	0.5	1.41	1.91
Thyroid	75	0.22	2.39	2.61
Other organ	25	0.46	1.40	1.86

Note: exact values are site dependent and will need to be confirmed after site selection

- **40CFR190.10b quantity limits based on GW-yr of electricity produced for fuel cycle:**
  - **Recycling exceeds current limits for ^{85}Kr (based on newly discharged UNF) and ^{129}I**
  - **Revise/update regulation to be risk based consistent with International Commission on Radiation Protection and or update with current cost and dose bases**
  - **Advanced Design Working Group between industry and National Labs to identify new technology for capture/conditioning of ^{85}Kr – perform risk and cost/benefit analysis**

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Engineering Challenges

- **Recovering small amounts of volatile fission products from large volumetric flow rates presents many challenges. Stack flow 150,000 m^3/hr of air - trace amounts of ^{129}I contamination.**
- **To achieve a reduction of risk to the public, the volatile fission products must be conditioned in a stable form, and stored or disposed safely.**
- **Recovering and concentrating readily dispersible material introduces potential new risk of exposure and contamination to the workers.**

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Environmental / Waste Management (1/4)

- ^{85}Kr
  - Noble gas. It is a non-soluble and chemically inert produced in trace amounts in nuclear fuel in a reactor. With a half-life of 10.7 years, the concentration of the gas will be dependent upon the age of the fuel recycled.
  - Control technology options
    - Cryogenic Distillation
      - Technology available
      - Safety Risk
    - Waste conditioning
      - Vacuum Pressure Swing Adsorption
      - Ion Implantation & Sputtering
    - Engineering Scale Demonstrated at the Tokai Facility in Japan by JNFL
  - Costly to implement

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Environmental / Waste Management (2/4)

- ^{129}I
  - Half-life of 15.7 million years. During dissolution, the majority of the iodine is released as I_2 into the dissolver off-gas where most will be trapped in the off-gas treatment. Trace amounts finds its way into the active cell ventilation system and the rest remains in the dissolution liquors and will follow the liquid waste streams in the process.
    - Rokkasho Recycling Plant implementing traps on solid media (silver beds) to capture trace amounts that pass the off-gas treatment – similar process under investigation for WTP
    - Evaluating conditioning for solid media
  - Further reductions will be considered as part of the overall ALARA goals for facility design

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Environmental / Waste Management (3/4)

- ^{14}C
  - Half life of approximately 5,700 years. During dissolution, part of the ^{14}C is released as CO_2 into the dissolution off-gas. However, a large fraction of ^{14}C remains in solution during this process step and is released into the off-gas stream during subsequent processing steps within the facility. Trapping ^{14}C will also trap CO_2.
  - Trapping techniques for small amounts of the ^{14}C will also trap the large amounts of CO_2 present in the air flow resulting in large volumes of material to be stabilized.
  - Complies with current regulations

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Environmental / Waste Management (4/4)

- ^{3}H
  - Half-life of approximately 12.3 years, is present as tritiated water exhibiting physical and chemical characteristics very close to water. It is difficult for effluent treatment processes to separate tritium from the water at the concentrations that will be present in a recycling facility.
  - 96% removal with current controls and conditioned as solid waste.
  - Remaining capture if required is an engineering issue not technical issue.
    - Technology would be energy intensive

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D&D Waste From Recycling

Recycling Facility D&D Waste Volumes

- The design of modern nuclear facilities including recycling plants integrates the lessons leaned from previous D&D operations to ensure final waste volumes are minimized. This is achieved by considering how to D&D a facility during the initial design.
- The waste generated by decommissioning a 2,500 ton/yr recycling plant can be put into context by comparing it to the waste generated over the 50 year life of the facility.
  - LLW: less than 20% of cumulated LLW generated during operations

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Advanced Separations

Engineering Considerations for Advanced Separation

- Criteria for final geological repository
- Commercial facility
  - Each separated product stream adds additional complexity in process operations, plant design and cost
    - Cs, Sr
      - Short half-life and will decay in vitrified HLW during interim storage of canisters at the recycling facility
    - Tc
      - Current plan to send to vitrified HLW
    - Am and Cm
      - Complexities with handling Cm - current plan to send to vitrified HLW
      - Am could be recycled as a transmutation fuel/target – multiple recycles in SFR to burn

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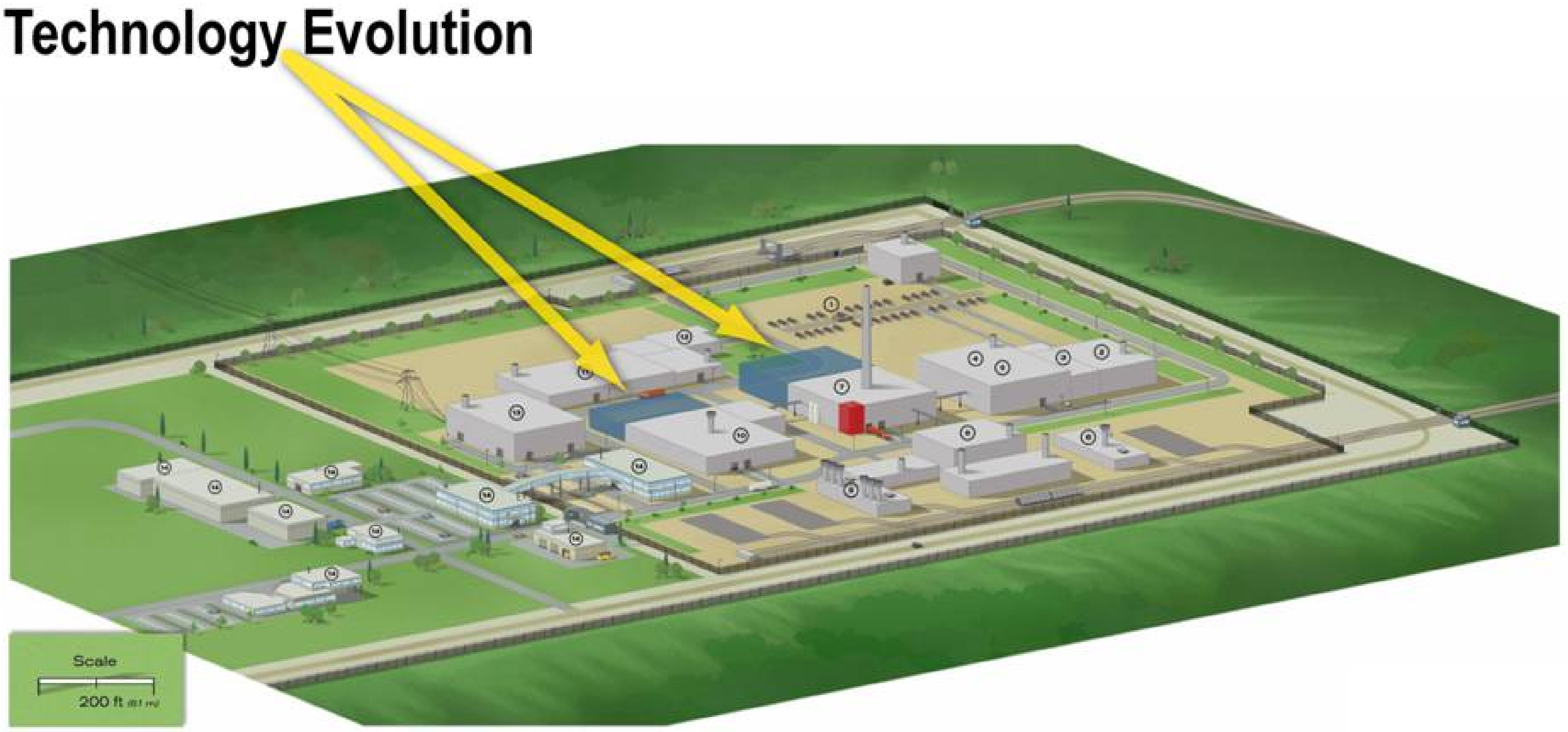
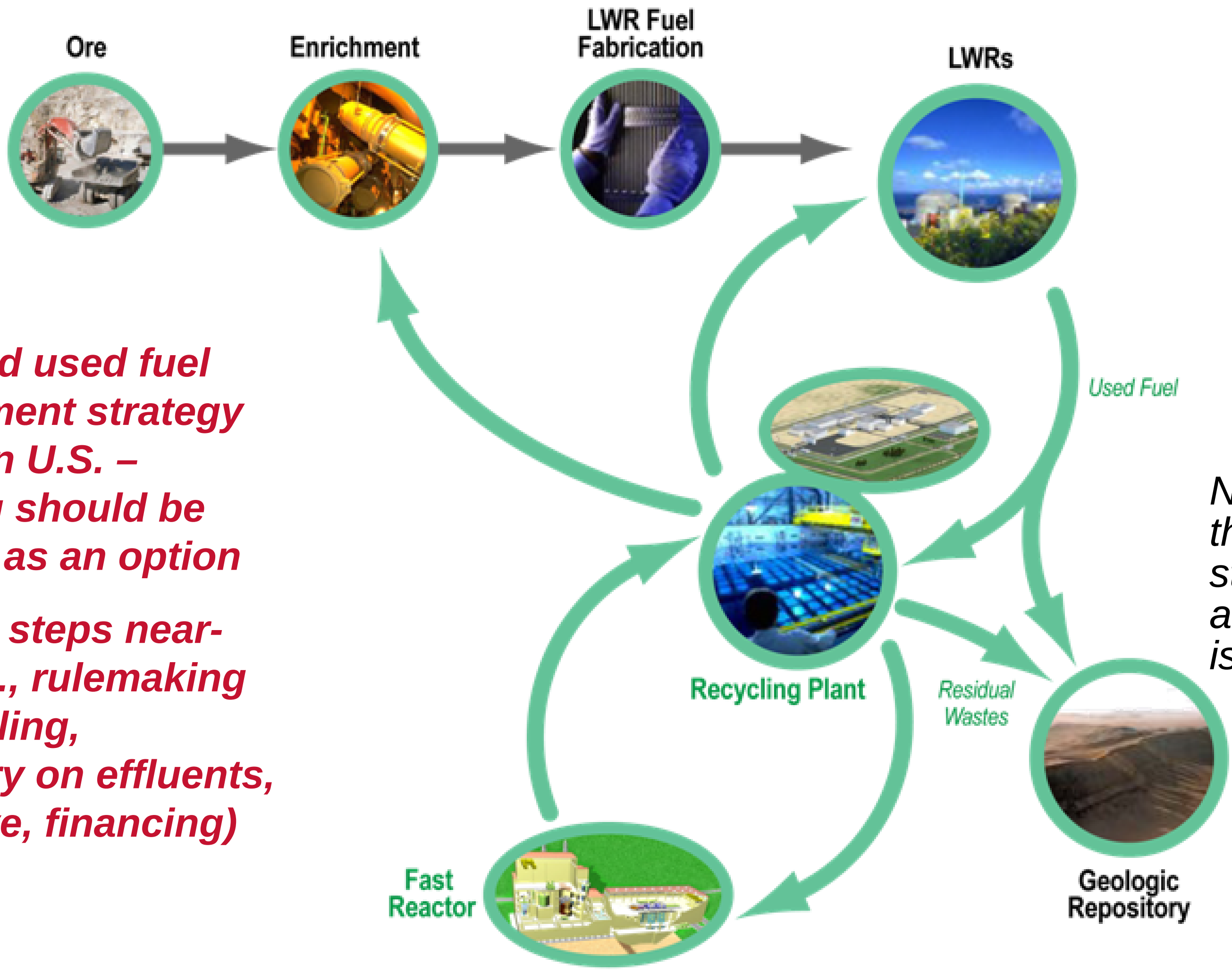
Am Separation Built as an Annex to Initial Facility



Industry engaged with National Labs in campaign managers meetings

Summary:
A Sustainable Back-End Solution



Integrated used fuel management strategy needed in U.S. – recycling should be included as an option

Enabling steps near-term (e.g., rulemaking for recycling, regulatory on effluents, legislative, financing)

No matter the back-end strategy, a repository is needed

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Backup Slides

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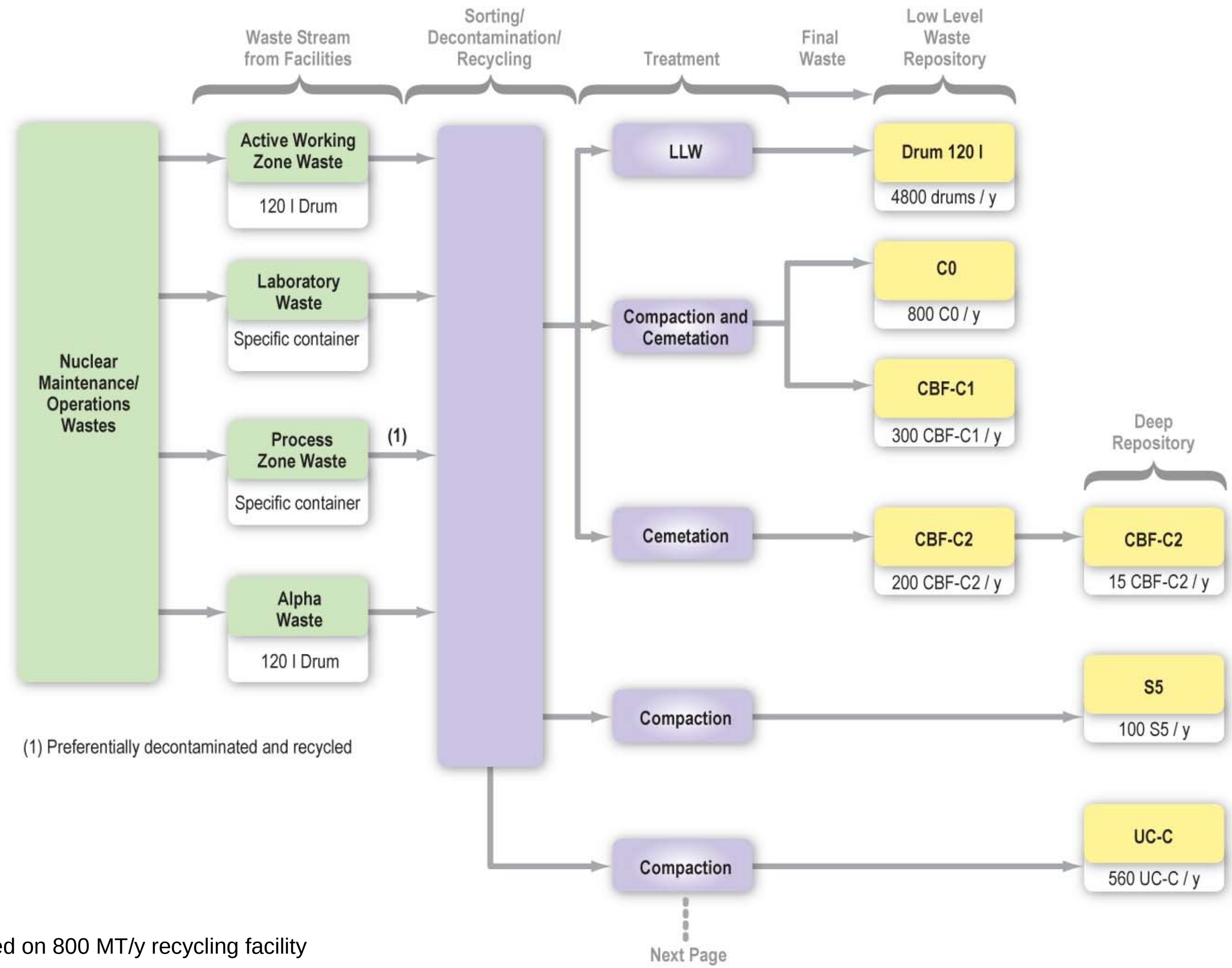
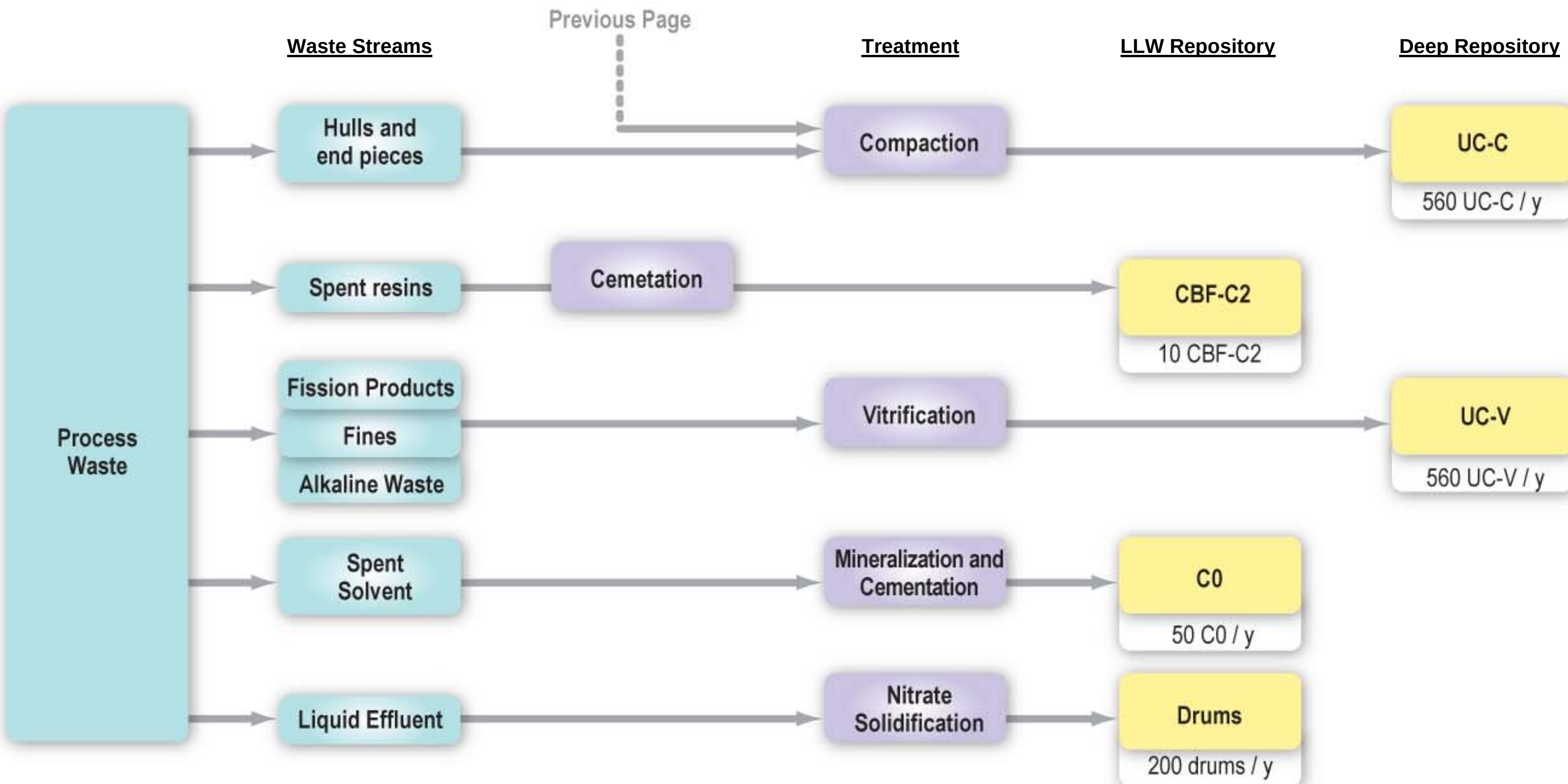
Expected Waste Streams for Recycling Facility (1/2)



*Based on 800 MT/y recycling facility

Expected Waste Streams for Recycling Facility (2/2)



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Comparison of HLW Canister to Defense Waste Canister

Characteristics	R7T7 Waste Form (CSD-V)	U.S. Defense HLW Canister
Canister height	~1.34 m	3.0 or 4.5 m
Canister outer diameter	0.43 m	0.61 m
Filled canister weight	< 500 kg	
Weight of glass in canister	~ 400 kg	up to 2000 kg
Maximum heat output at the time of shipment	2 kW	1.5 kW
Dose rate	Can be > 10^5 rad/h	
Canister material	Stainless steel	Stainless steel
Closure method	Welding	Welding
Handling features	Concentric neck and flange allow the use of grapples	Concentric neck and flange allow the use of grapples

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