U.S. DEPARTMENT OF ENERGY | Nuclear Energy

Fuel Cycle Technologies

System Architecture Evaluation

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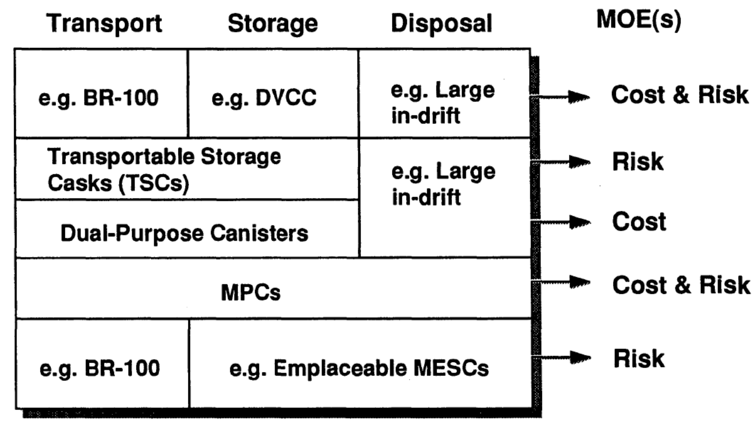
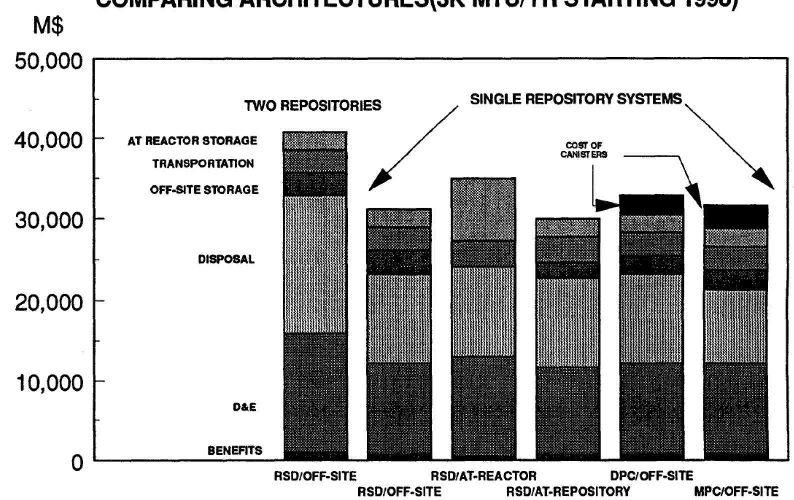
Motivation

- **In the 1990s the U.S. DOE completed a number of systems analyses investigating consolidated interim storage as part of the waste management solution**
- **These analyses are "dated" and conditions have changed**
  - Utility evolution and progress loading dry storage systems
  - Consideration of different geologic disposal environments
- **Need to update back-end system architecture studies**
- **Need to update tools for evaluating the back-end of the fuel cycle**
- **Need recognized by both the NWTRB and the BRC**



DVCC - Dry Vertical Concrete Cask
MESC - Multiple Element Storage Canister

COMPARING ARCHITECTURES(3K MTU/YR STARTING 1998)



TRW Environmental Safety Systems Inc., System Architecture Study, A00000000-01717-6700-00003 Rev. 0, July 26, 1994

Considerations for a Future UNF Management System

- **Direct disposal of dual-purpose canisters (DPCs) is highly uncertain**
  - Feasibility would have to be demonstrated and suitable site identified/selected
  - Re-packaging of DPCs will be required if direct disposal is not feasible
  - Multi-year feasibility evaluation required; initiated in FY12
    - *Complex problem (recall, YM did not accept DPCs for direct disposal)*
- **Implementation of standardized canisters**
  - Could have system-level benefit, depending on when deployed
  - Uncertainty regarding standard canister size; repository media unknown
  - Still would have to manage legacy DPCs
  - Multi-year evaluation/implementation required; initiated in FY12
- **Legacy and continued use of dual purpose canisters (and single purpose storage casks) must be managed**
  - Wide range of systems in use (vertical, horizontal; ~ 30 different vendors/designs)
  - Inventory and mix (vertical/horizontal) depends on start date of UNF acceptance and acceptance rate
  - Influences future storage facility design
  - Affects magnitude of future re-packaging

Considerations for a Future UNF Management System

- **Central Storage Facility (CSF) concepts can differ, depending on UNF management approach taken**
  - Start dates of CSF and repository
  - Acceptance and disposal rate
  - Fuel receipt - canisters, bare fuel
  - Storage method – dry (vertical/horizontal canisters, vaults); bare fuel storage (pools)
  - Imposed capacity limits of facility
- **Strategy for managing UNF in fuel pools once CSF begins operation will affect CSF design and future waste packaging/re-packaging**

All Canistered

- *Transport all fuel in DPCs*
- *Dry canister storage*
- *Re-packaging of all DPCs*

vs.

Canistered and Bare

- *Transport fuel from pools in re-useable casks*
- *Dry canister + bare fuel storage*
- *Reduced number of DPC re-packaging + bare fuel packaging*

Objectives of the UFD System Architecture Effort

- Provide quantitative information with respect to the broad UNF management considerations
- Develop an integrated approach to evaluating storage, transportation, and disposal options, with emphasis on flexibility
- Evaluate impacts of storage choices on disposal options
- Identify alternative strategies and evaluate with respect to cost and flexibility
- Considerations include repository emplacement capability, thermal constraints, repackaging needs, storage and transportation alternatives, impacts on utility operations, etc.

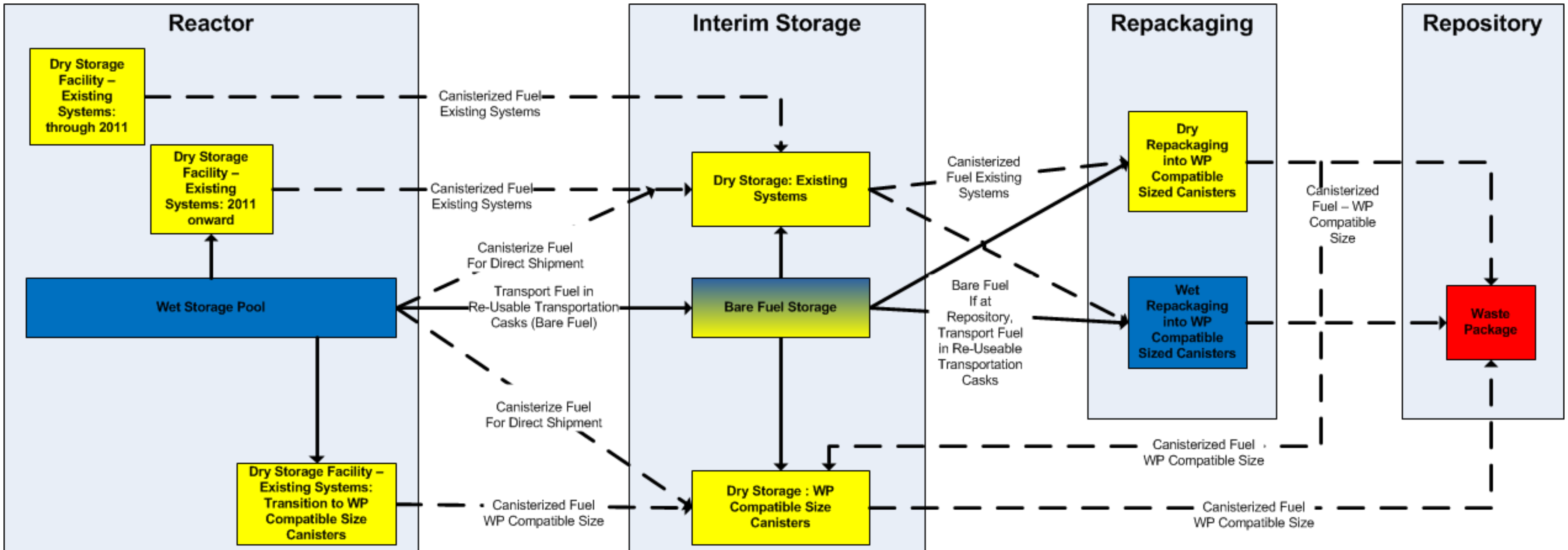
Overview of FY12 Activities

- **Developed framework of potential UNF disposition pathways from at-reactor storage (wet → dry) through interim storage to ultimate disposal**
  - Assuming that canisters will need to be re-packaged into disposal canisters
- **Selected disposition pathways for evaluation in FY12**
- **Determined evaluation assumptions, boundary conditions, and system inputs (acceptance rates, start dates)**
- **Developed UFD Transportation Storage Logistics (TSL) simulation tool from legacy codes (CALVIN and TOM)**
- **Conducted UNF logistic evaluations of selected disposition pathways**
- **Developed modular design concepts for Centralized Storage Facilities (CSF) and packaging/re-packaging plant**
- **Utilized logistic simulation results and modular design concepts to lay out facilities needed for each case evaluated**

Objective of FY12 Activities:

1) Develop methodologies, approaches, and tools (Capability Development)
2) Evaluate select UNF disposition scenarios (Capability Demonstration)

Disposition Pathway Overview



At-Reactor Fuel Management: Options

1. Wet Storage Fuel Management
   - 1a. Transfer to dry-storage to maintain full core off-load capability
   - 1b. Accelerate transfer to dry storage (age ≥ 5 yr)
2. Continue off-loading of fuel in wet storage pools into existing sized dry storage systems
3. Initial off-loading of fuel in wet storage pools into existing sized dry storage systems – transition to WP compatible sized dry storage system at T = 20xx.
4. Transport all fuel in wet storage pool to CSF (when operational and has bare fuel storage capacity) in re-useable transportation casks
5. Canisterize fuel in wet pool for direct shipment to CSF (when operational and does not have bare fuel handling capability)
   - 5a. Existing dry storage systems
   - 5b. WP compatible sized dry storage systems

CSF Fuel Management: Options

1. Wet storage capability at CSF
   - 1a. Maintain fuel in wet storage
   - 1b. Transfer to existing dry storage systems
   - 1c. Transfer to WP sized canisters
2. Re-packaging locations
   - 2a. At CSF
   - 2b. At repository
3. Re-packaging technology alternatives
   - 3a. Wet
   - 3b. Dry
4. Received fuel at CSF in existing dry storage system sized canisters
   - 4a. Store as-is
   - 4b. Repackage into WP compatible size canisters and store

Disposition Pathway Evaluation

- **Identified 9 potential disposition cases (and minor variants) that consider**
  - At-reactor UNF management
    - *Transport all UNF in canisters or transport bare fuel in pools in re-useable transportation casks*
    - *Transition to loading disposable canisters at-reactor*
  - Packaging/Re-Packaging
    - *At CSF or at repository*
    - *Upon receipt at CSF or upon shipment to the repository*
- **Selected disposition cases for evaluation in FY12**
  - At-reactor UNF management
    - *Transport all UNF in large canisters or transport bare fuel in pools in re-useable transportation casks*
  - Packaging/Re-Packaging
    - *At CSF or at repository*
    - *Upon shipment to the repository*

Down-select considered commonality of capability requirements, level of complexity, and flexibility

Assumptions and Input / Boundary Conditions

- **Assumptions**
  - Disposition of Used LWR Fuel in a Once-Through Fuel Cycle
  - Reactor fleet is limited to the current 104 operating reactors
  - Reactors will receive life extensions to operate for 60 years
  - Projected fuel inventory at reactor; wet and dry
  - Oldest-Fuel-First (OFF) allocation priority (*determines which sites ship in a given year*)
  - Youngest-Fuel-First (YFF) shipment from reactors (*determines which fuel is shipped from each site*)
  - First-In-First-Out (FIFO) shipment from storage facility
  - Reactors complete off-load of pools to dry storage 5 years after shutdown
- **Input/Boundary Conditions**
  - Single CSF and geologic repository
  - CSF/geologic repository available: 2020/2040, 2020/2055, 2035/2055
  - Geologic repository available: 2040, 2055
  - Acceptance rates: 1500, 3000, 6000 MT/yr
  - Waste package sizes: 4/9, 12/21, 21/44 PWR/BWR assembly capacity
    - *Covers range of disposal concepts under consideration by UFD to date; feasibility of direct disposal of large DPCs are part of ongoing investigations*

Did not evaluate all combinations in FY12

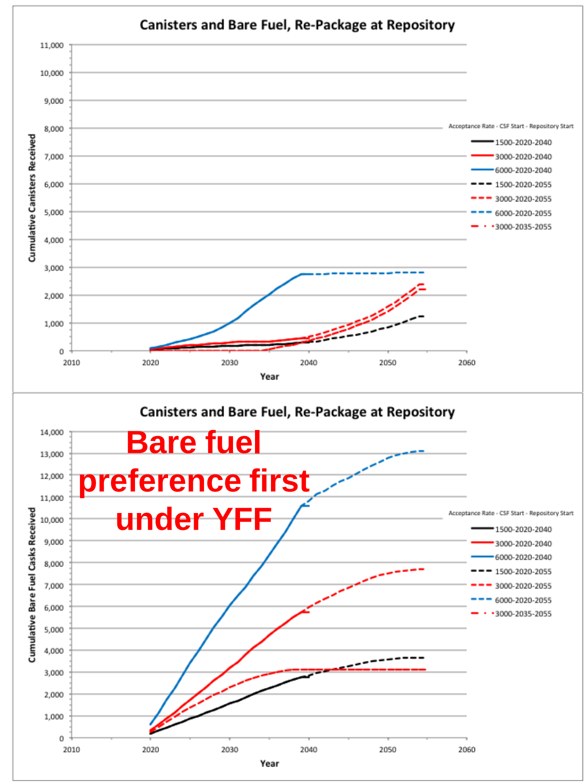
Logistics Modeling

- **Utilized the UFD Transportation Storage Logistics (TSL) simulation tool to evaluate the cases and input/boundary conditions**
  - Modified and coupled two existing software tools
    - *Civilian Radioactive Waste Management Analysis and Logistics Visually INteractive Model (CALVIN)*
    - *Transportation Operations Model (TOM)*
  - Fuel discharge projection revised based on 2011 EIA forecast
    - *Everything is projection forward from 2002 (last RW-859 data)*
- **TSL tracks individual fuel assemblies through their disposition pathway**
  - Used fuel pool → dry storage casks (by reactor, vendor model, size)
  - At-Reactor Storage → storage at a Consolidated Storage Facility (CSF)
  - CSF → repository
  - Packaging/Re-packaging into disposal canisters
- **Logistics results used to establish requirements for UNF management facilities (storage, packaging, re-packaging)**
- **End state: Production of Disposal Canisters**

	4-PWR/9-BWR	12-PWR/24-BWR	21-PWR/44-BWR
PWR Waste Packages	52,250	17,417	9,952
BWR Waste Packages	30,333	11,375	6,205
Total Waste Packages	82,583	28,792	16,157

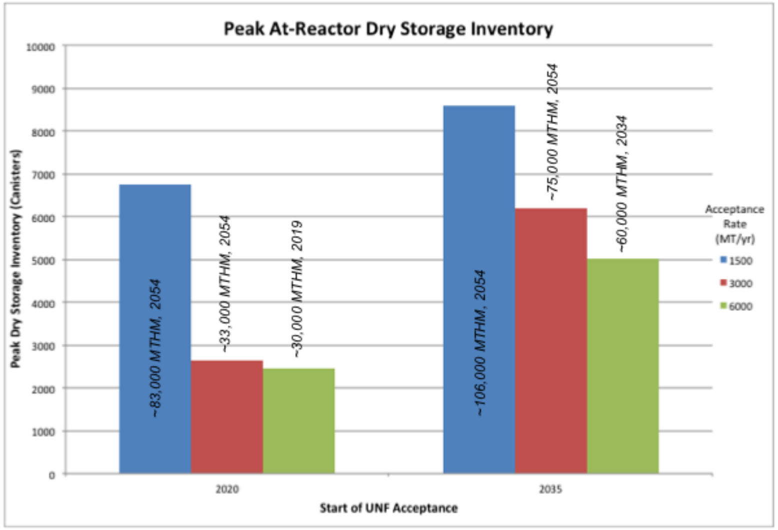
Insights Gained from Logistics Modeling
(Preliminary Results)

- **Higher throughput rates lead to larger facilities**
  - 1500 MT/yr: smaller storage and re-packaging facilities; larger/longer at-reactor storage
  - 3000 MT/yr: larger storage and re-packaging facilities; smaller/reduced at-reactor storage
  - 6000 MT/yr: large storage and re-packaging facilities; marginally smaller/small additional reduction in at-reactor storage
- **UNF acceptance priority (i.e., OFF, YFF), acceptance start date, acceptance rate, and UNF management strategy will impact the overall UNF management system, facility design concepts, and facility configuration**
  - At-reactor UNF management and shipment defines the “boundary condition” to which the system will “respond”
  - Lower the acceptance rates or delay in start of acceptance “hardens” this “boundary condition,” resulting in reduced flexibility later
    - *More UNF will be placed in at-reactor dry canister storage system*
  - Affects timing of downstream receipts (arrival of canisters, and bare fuel casks if included)



Insights Gained from Logistics Modeling
(Preliminary Results)

- **Start of acceptance and the acceptance rate will impact on-site dry storage requirements**
  - Significant decrease between 1500 MT/yr and 3000 MT/yr acceptance rate; reduced decrease between 3000 MT/yr and 6000 MT/yr
  - Higher acceptance rates may not eliminate need for additional on-site dry storage when reactor fleet begins to shut down unless acceptance is "managed"
    - YFF still requires additional dry storage when reactors shut down
    - Straight OFF would require additional on-site dry storage



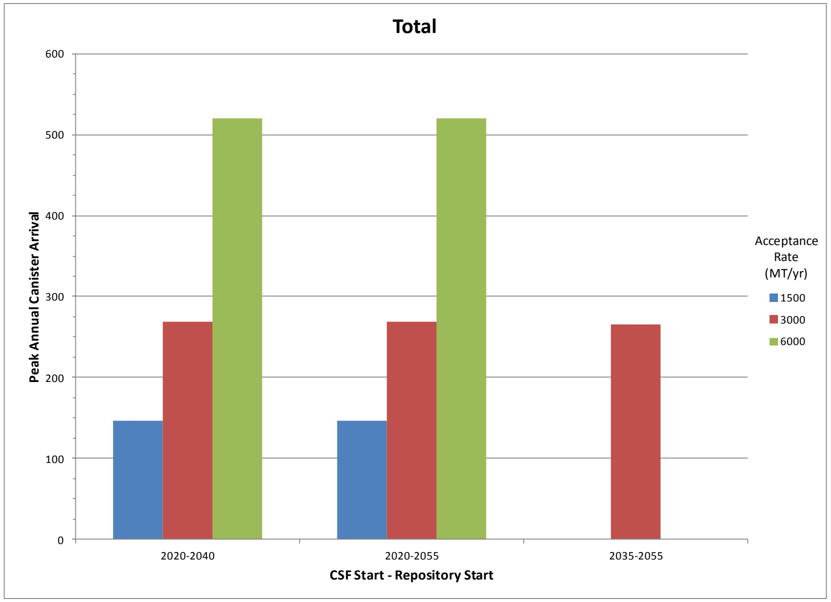
- **Alternate strategies for acceptance from reactors and subsequent shipment to a repository may also allow for optimization of down-stream facilities**
  - FIFO from CSF to repository is an initial assumption that may not be how the system is operated
  - Treat consolidated storage facility as an integrated UNF management facility to act as a buffer between at-reactor UNF management needs and future repository requirements
    - Optimize shipments from reactors to minimize additional on-site dry storage requirements
    - Optimize shipments from the CSF to the repository to meet repository requirements while minimizing processing facility requirements
  - May require additional CSF storage capacity
  - Additional evaluation needed

Insights Gained from Logistics Modeling

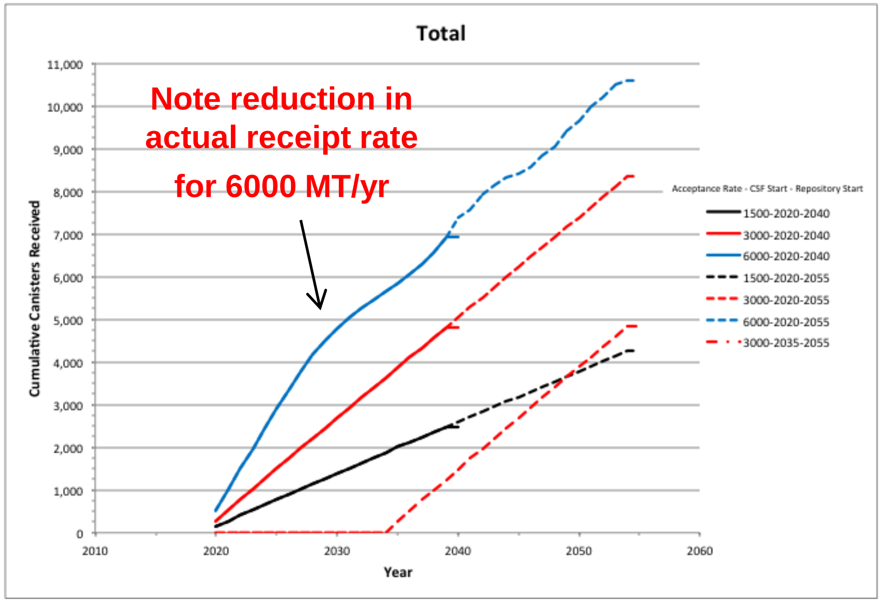
(Preliminary Results)

- **Processing rates and inventories scale with UNF throughput rate**
- **High acceptance rates (i.e., 6000 MT/yr) lead to large facilities and supporting infrastructure**
  - Large capacity storage facilities
  - High processing capability that may only be needed for a relatively short time; under-utilized facilities
    - *Available fuel transported relatively quickly – rate then matches discharge*

Peak CSF Canister Receipt Rate
All Canisters, Re-Package at Repository



Cumulative CSF Canister Receipt
All Canisters, Re-Package at Repository



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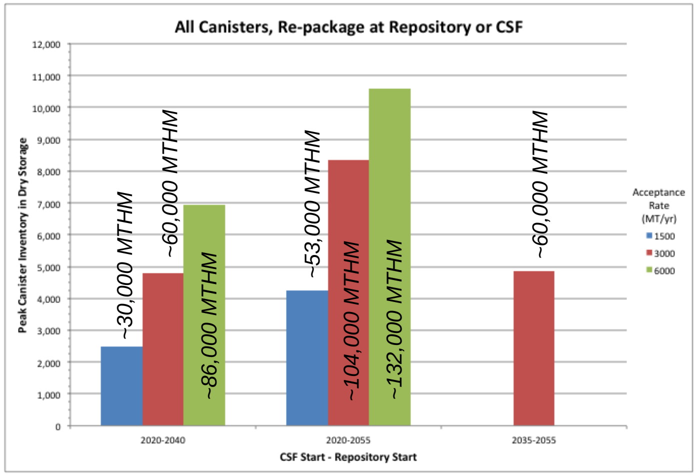
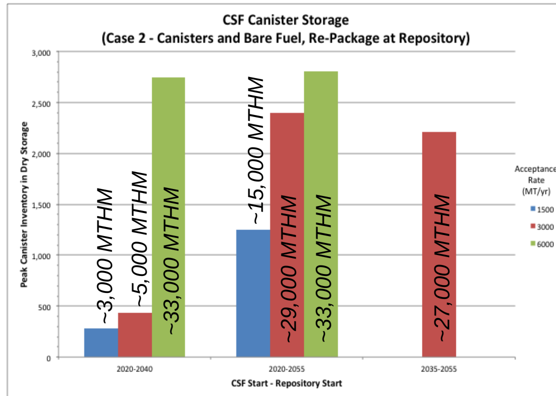
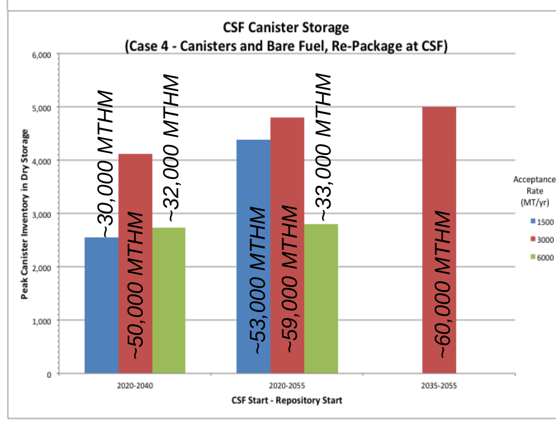
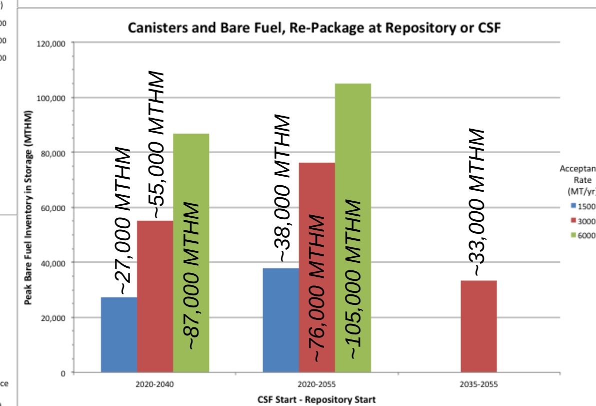
Insights Gained from Logistics Modeling
(Preliminary Results)







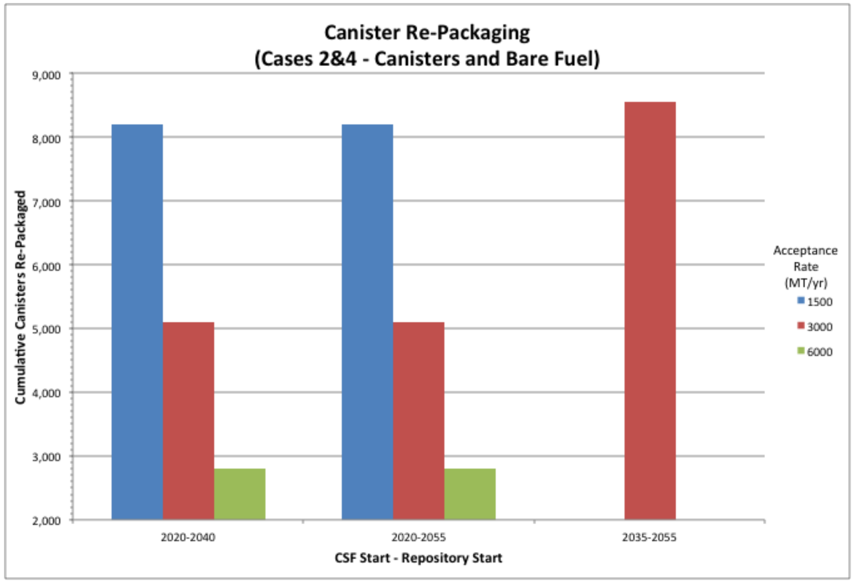
NOTE : SCALE IS DIFFERENT ON CHARTS



- **Dry storage at a CSF will be required for dry storage systems loaded at-reactor**
- **Acceptance rate and duration between start of CSF and repository operations affects storage capacity requirements**
  - Any additional decay storage would increase requirements
- **Maintaining bare UNF can reduce canister storage at a CSF**
  - Trade-off is bare fuel storage

Insights Gained from Logistics Modeling
(Preliminary Results)

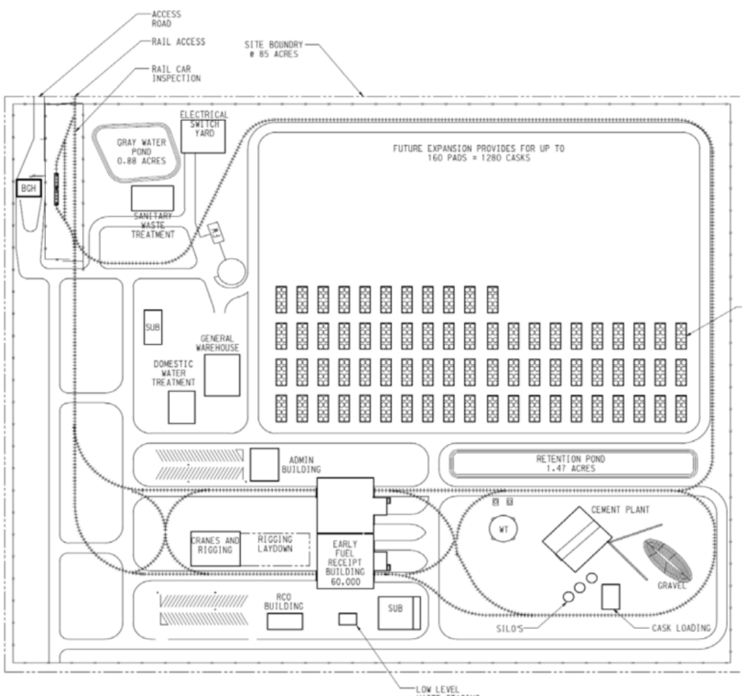
- **A large-scale UNF handling effort will be needed regardless of the UNF management strategy, acceptance rates, and acceptance start dates**
  - There will always be a need to re-package large canisters unless the direct disposability of such canisters is shown to be feasible
  - If all UNF is placed in such canisters, ~11,200 could have to be re-packaged
  - Handling bare fuel at central storage facilities can reduce the number of canisters that would have to be re-packaged
    - *Any potential benefit of not having to re-open canisters reduces for lower acceptance rates and/or delay in the start of acceptance*
    - *Have to store and package bare fuel*



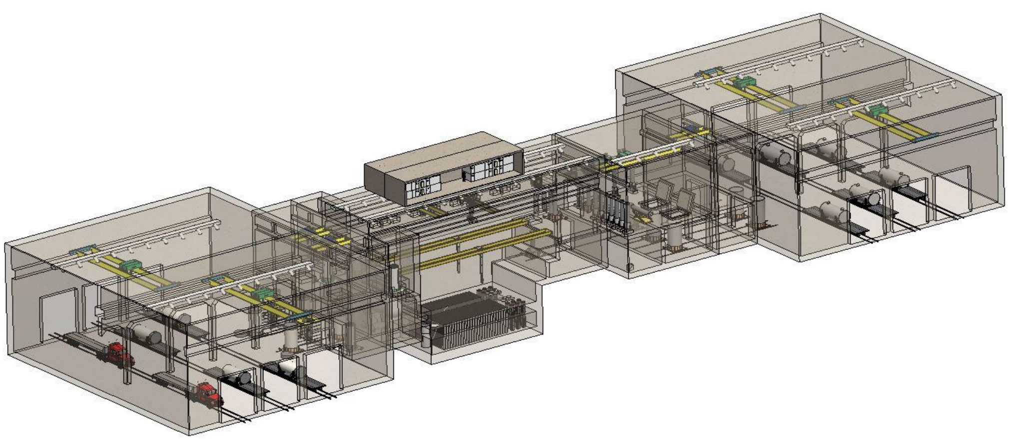
Facility Concepts

- **Developed modular design concepts for dry (vertical and horizontal casks) and wet (pool)**
- **Modular approach allows for constructing facility lay-outs for different scenarios and logistics results**
- **Unit operation times estimated for all handling/processing steps**

Vertical Dry Storage



Packaging/Re-Packaging



Insights Gained from Evaluating Facility Concept Configurations

(preliminary results)

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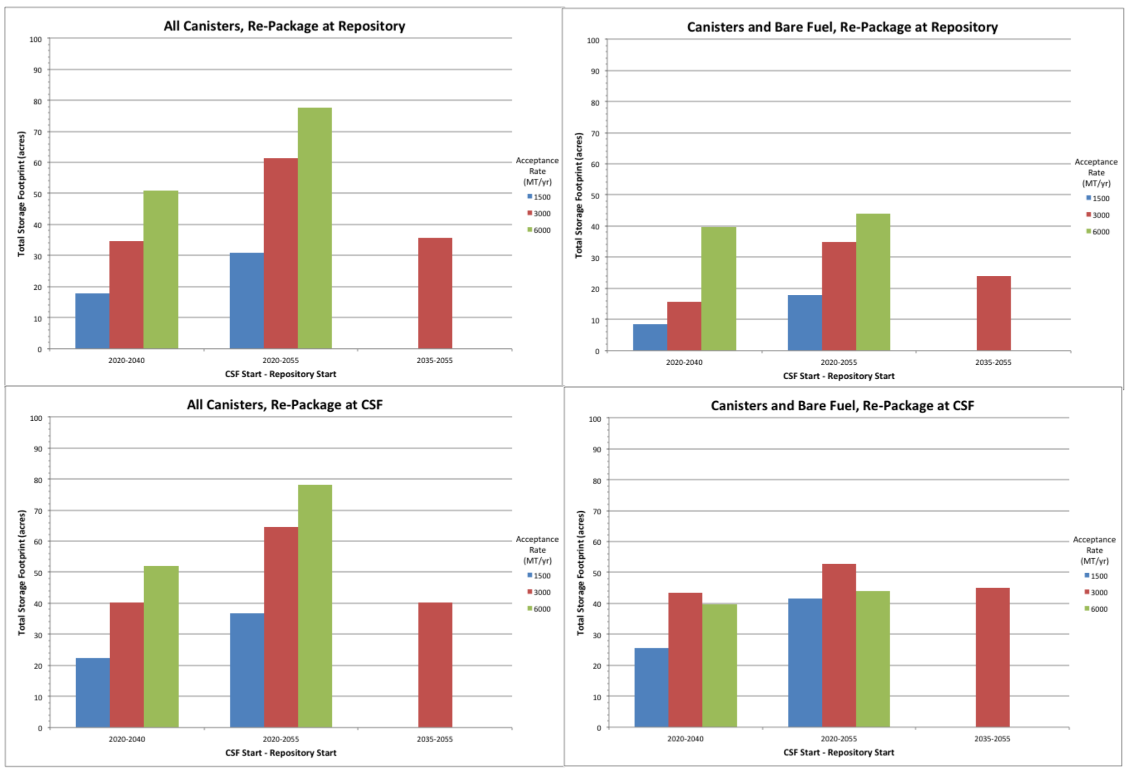
- **Total storage footprint increases with acceptance rate and duration between start of CSF and repository operations**
- **Bare fuel storage can reduce facility storage footprint**
- **Storage facility size likely to increase if it is used for decay storage**



- Vertical pad:
  - 30 ft x 80 ft
  - 8 Canisters per Pad
- Horizontal module:
  - 52 ft x 89 ft
  - 12 Canisters per Module
- Pool Basin:
  - 158 ft x 60 ft (x 55 ft deep)
  - 3500 Assemblies per Basin

NOTE : Does not include footprint that would be needed for infrastructure and support facilities or required spacing

Insights Gained from Evaluating Facility Concept Configurations
(preliminary results)

- **Larger UNF throughput rates lead to larger processing bay requirements**
  - Into/out of storage
  - Packaging/re-packaging facility stations (receipt, welding, release)
  - Observation: Higher acceptance rate (6000 MT/yr) does not fully utilize all bays for an extended duration
- **Placing the entire UNF inventory in large canisters does not appear to require an increase in the packaging/re-packaging facility capabilities versus maintaining bare fuel**
  - Always a need to re-package canisters – capability will always be required
- **Use of large canisters for the entire inventory of UNF increases the number of canisters that would have to be opened, unless their disposability can be demonstrated**
  - Could have a broader system impacts
  - ~11,200 canisters versus a reduced number – see Slide 16
    - *Peak arrival occurs early, then decreases significantly*

Conclusions

- **FY12 Objectives achieved**
  - Developed methodologies, approaches, and tools (Capability Development)
  - Evaluated select UNF disposition scenarios (Capability Demonstration)
  - Re-established important, foundational capability to assess potential UNF management options

- **FY12 Evaluation provided insight into potential UNF disposition pathways and identified areas where additional work are needed**
  - Logistics and facilities report to be completed as draft October 30th, 2012
- **FY13 activities**
  - Develop worker exposure methodology and implement in TSL
    - *Assess FY12 cases*
  - Continued TSL development to implement blending/aging at the CSF and alternative UNF shipment strategies from the CSF
    - *Assess FY12 cases*
  - Identify and evaluate bare fuel storage alternatives at CSF (i.e., vaults, single purpose casks)
  - Inclusion of cask/fleet maintenance facilities in framework
  - Evaluate sensitivity regarding CSF wet pool density
  - Initiate assessment of advanced re-packaging techniques, gaps (dry, automated, remote)
  - Initiate process flow diagram/process node descriptions