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Transportation Logistics

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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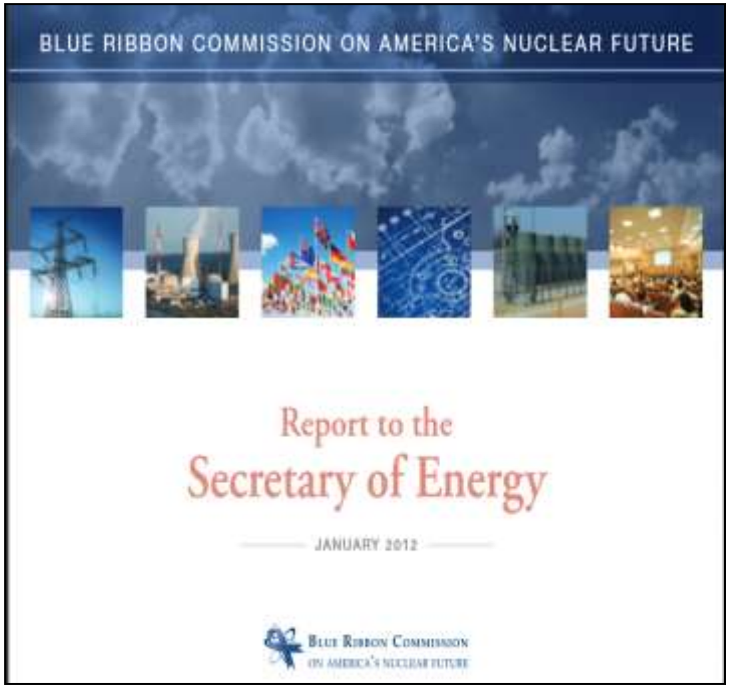
BRC and Administration Strategy

Emphasized Interim Storage as Part of an Integrated Waste Management System.

"Consolidated Storage would...

- Allow for the removal of 'stranded' spent fuel from shutdown reactor sites.
- Enable the federal government to begin meeting waste acceptance obligations.
- Provide flexibility to respond to lessons learned from Fukushima and other events.
- Support the repository program.
- Provide options for increased flexibility and efficiency in storage and future waste handling functions".



- "The Administration agrees that interim storage should be included as a critical element in the waste management system.
- The Administration supports a pilot interim storage facility initially focused on serving shut-down reactor sites."

Consolidated Interim Storage Facility (ISF) Concept

Pilot ISF (2021)

- 5,000 to 10,000 MTU.
- 1,500 MTU/yr receipt rate .
- Dry storage containers from shutdown sites with “stranded fuel”.
- Transport containers in transportation overpack.
- 9 stranded sites use 13 canister designs, 8 storage, and 7 transport overpack designs.

Full Size ISF (2025)

- 70,000 MTU or greater.
- 3,000 to 4,500 MTU/yr receipt rate.
- Dry storage containers and bare fuel from all the remaining reactor sites:
  - 4 new shutdown sites
  - 100 operating reactor sites

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Prepare for the Large-Scale Transportation of Spent Nuclear Fuel (SNF) and High Level Radioactive Waste (HLW)

- Collaborating with stakeholders through State Regional Groups and tribal representatives.
- Design, testing, and acquisition of rail cars and transportation casks.
- Initiate development of S-2043 Compliant Railcars.
- Removing SNF from the shutdown reactor sites.
- Removing fuel from all the reactor sites and DOE sites.

Removing SNF from the Shutdown Reactor Sites

- Assist in the process of selecting appropriate strategies for transporting the Spent Nuclear Fuel (SNF) from the shutdown sites.
- Explore the logistics and costs associated with shipping SNF to a hypothetical storage facility.
- Understand what resources and time would be required to unload the shutdown sites.
- Consider possible scenarios of transportation of SNF from the shutdown sites to a potential consolidated storage facility.
- Identify major factors affecting scenario performance.
- Rank (compare) the scenarios based on their performance.

NOTE: the locations of the consolidated storage facilities and the starting date of their operation were selected arbitrarily.

Scenario Parameters

A hypothetical consolidated storage facility starts its operations in 2021.

1. Campaign duration: 1, 2, 3, 4, 5, 6, and 8 years.
2. Fuel selection approach:
   - Older Fuel First
   - Sequential unloading when possible.
   - Parallel unloading when possible.

Campaign duration | Fuel selection approach

9 Pickup Schedules
(not all the possible combinations)

3. Consist size: 1-car, 2-cars, 3-cars, and site-specific (5 cars for Maine Yankee).
4. Location of a hypothetical consolidated storage facility: SE,SW, NE, and NW.
5. Location of a maintenance facility: co-located and not co-located with the consolidated storage facility.
6. Casks: using NAC-MAGNATRAN instead of NAC-STC casks at Haddam Neck, Yankee Rowe, and La Crosse sites.

31 different scenarios
(not all the possible combinations)

Shutdown Reactor Sites

Trojan: TranStor
Holtec MPC canisters

Zion: NAC MAGNASTOR
TSC canisters

Yankee Rowe: Nac-MPC
MPC canisters

Humboldt Bay: Holtec HI-STAR
MPC canisters

LaCrosse: Nac-MPC
MPC canisters

Main Yankee: Nac-UMS
MPC canisters

Rancho Seco: TransNuclear
Nuhom canisters

Big Rock Point: W150
W74 canisters

Connecticut Yankee: Nac-MPC
MPC canisters

Shutdown Reactor Site Location

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<u>Hypothetical consolidated storage facilities:</u>

SE – Southeastern USA, SW – Southwestern USA, NE – Northeastern USA, NW – Northwestern USA

Shutdown Site Inventory

Site	Fuel Type	Number of Assemblies	Storage Canister	Number of Canisters	Transportation Cask
Big Rock Point	BWR	441	W74	7	TS-125
Connecticut Yankee	PWR	1019	MPC-26, 24	40	NAC-STC
Maine Yankee	PWR	1434	UMS-24	60	NAC-UMS
Yankee Rowe	PWR	533	MPC-36	15	NAC-STC
Rancho Seco	PWR	493	24PT	21	MP187
Trojan	PWR	780	MPC-24E/EF	33	HI-STAR 100
Humboldt Bay	BWR	390	MPC-80	5	HI-STAR 100
La Crosse	BWR	333	MPC-LACBWR	5	NAC-STC
Zion 1 and 2	PWR	2226	TSC-37	61	NAC-MAGNATRAN
Total		7649		247	

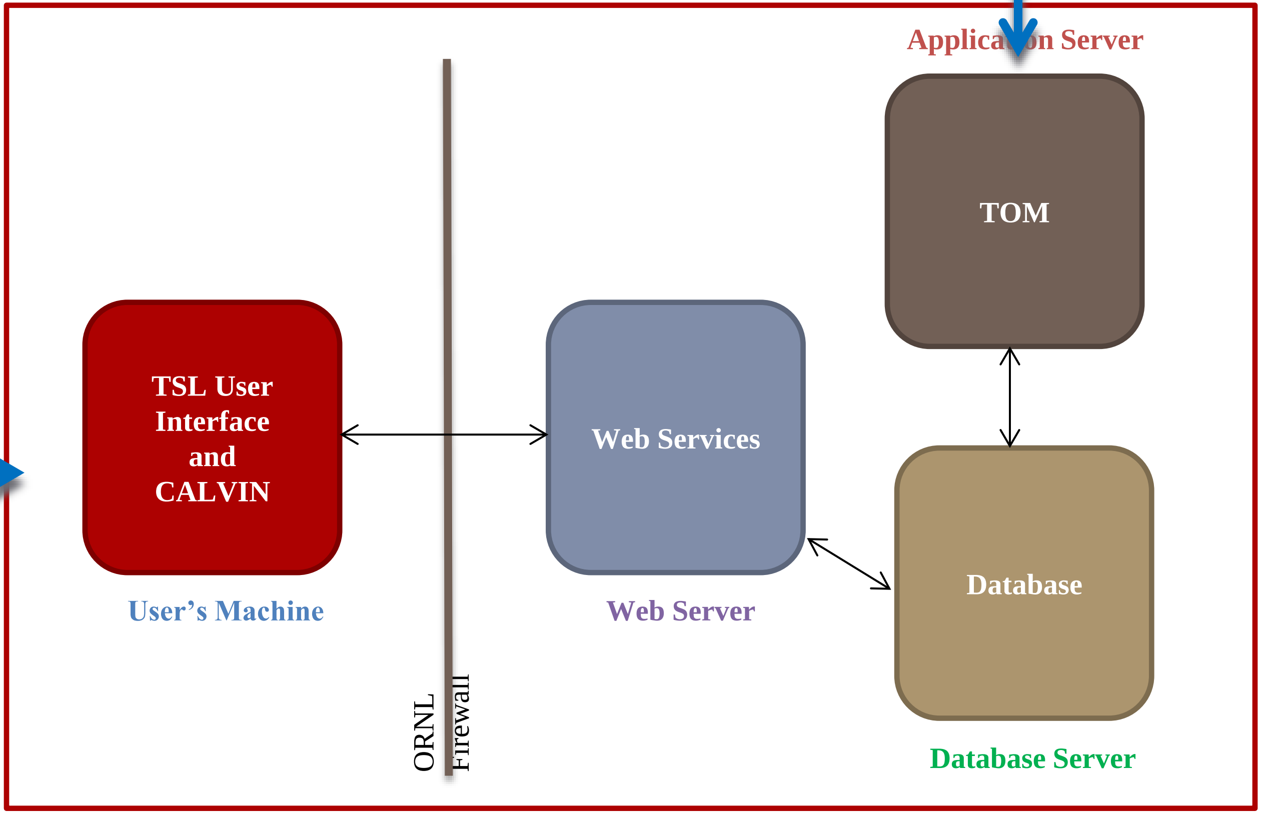
Logistical Simulation Tool TSL-CALVIN

TOM - Transportation Operations Model:

- Models transportation operations.
- Calculates transportation fleet.
- Calculates transportation costs.

TSL - Transportation Storage Logistics Model:

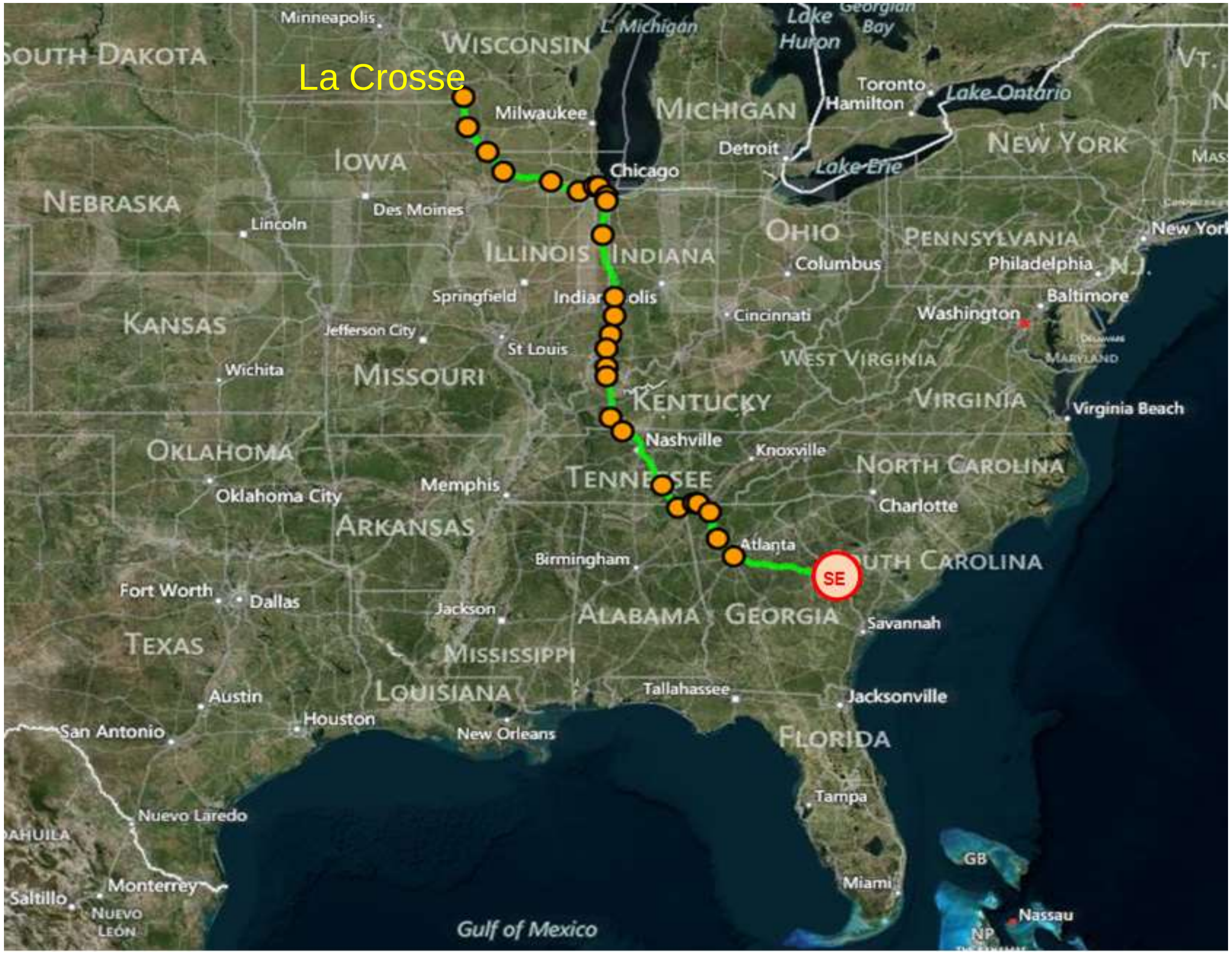
- Generates pickup schedule.
- Calculates all costs, except transportation costs.
- Includes database with the UNF projection, reactor site information, and cask information.



TOM Database:

- Cask data.
- Processing times.
- Costs (casks, transportation, security, maintenance and other).

Calculated Route from LaCrosse to a Hypothetical Storage Facility in SE



The duration of each trip is calculated based on the transportation routes.

<u>**Assumption:**</u> The transportation networks in the future will be the same as they are now.

Transportation Cycle in TOM

(begins and ends at the fleet maintenance facility)

The following activities are simulated:

- ❑ Traveling to the pickup site.
- ❑ Loading the fuel into casks and onto the transportation asset.
- ❑ Traveling to the storage facility.
- ❑ Unloading the cask, unloading the fuel, and loading the empty cask onto the transportation asset.
- ❑ Traveling to the cask maintenance facility.
- ❑ Performing cask maintenance.
- ❑ Traveling to the fleet maintenance facility.
- ❑ Performing fleet maintenance.

Assumptions:

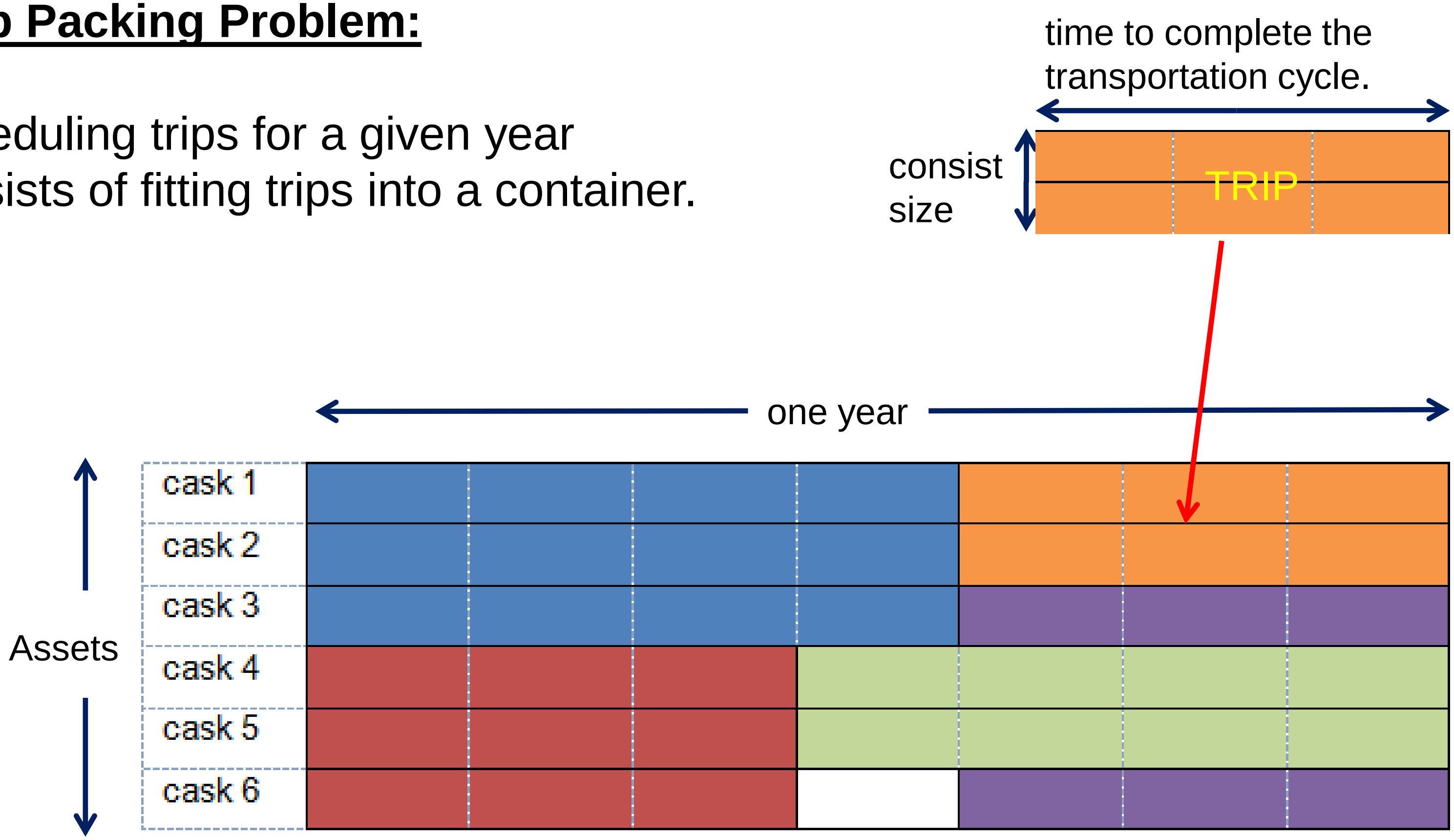
- ➢ There can only be one consist loading at the reactor at a time.
- ➢ The unloading capability at the consolidated storage facilities is unlimited.

Scheduling Algorithm in TOM

The individual items (trips) are packed into the container to minimize the container height. Minimizing the height becomes an asset-minimization problem.

Strip Packing Problem:

Scheduling trips for a given year consists of fitting trips into a container.



Transportation Costs in TOM

Capital Costs

- Purchase Buffer Railcar
- Purchase cask
- Purchase Cask Railcar
- Purchase Escort Railcar

Maintenance Costs

- Annual cask maintenance
- Escort fleet maintenance
- Standard cask maintenance
- Transport fleet maintenance

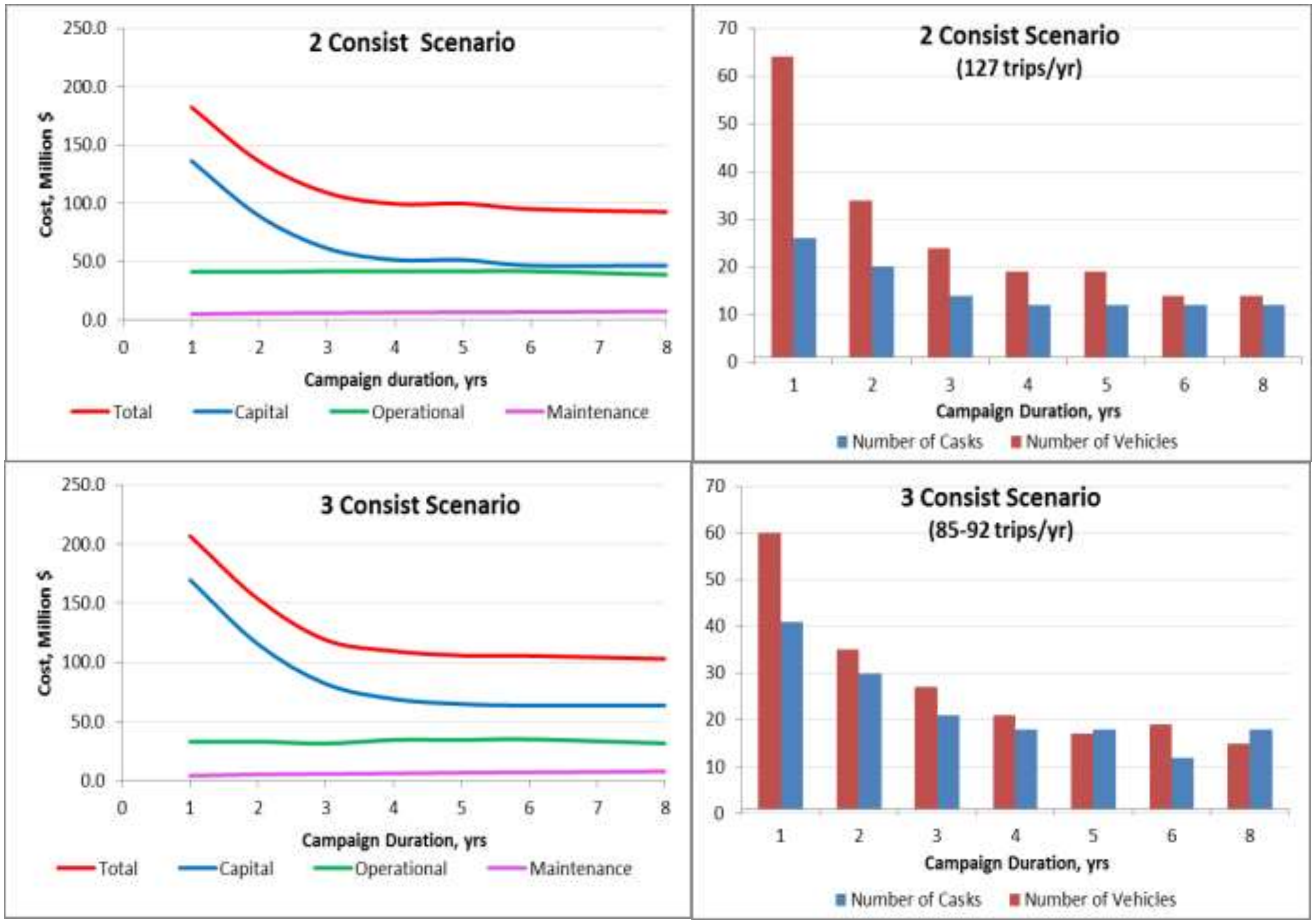
Operational costs

- Barge (if applicable)
- Crane
- Heavy haul (if applicable)
- Mainline rail
- Security labor
- Shortline rail
- Switching fee
- 180c charges.

Assumption: The calculated mainline rail costs are an approximation of what the actual charges would be. The costs are a function of the weight of the casks, the number of cask cars, and the distance travelled.

Campaign Duration

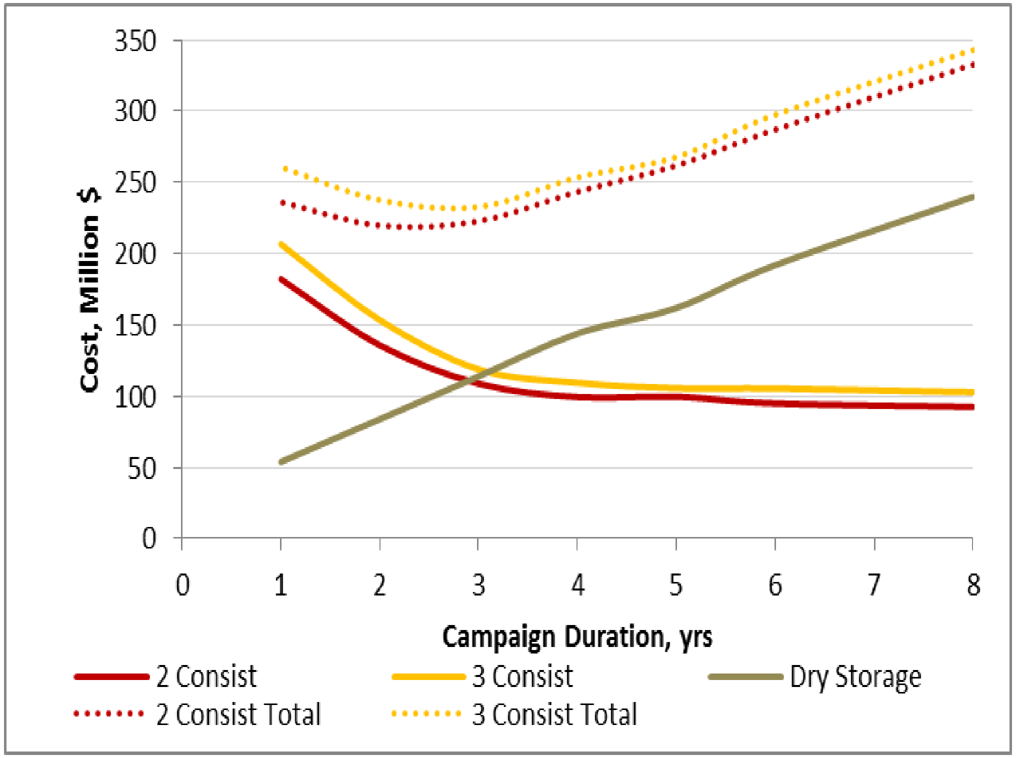
Scenario parameters: parallel schedule, storage in SE USA, co-located maintenance facility.



- The high total cost of the short duration campaigns is due to the high capital costs.
- The 2-car scenarios have higher operational costs (more trips per year), but lower capital costs (fewer casks).

Total Transportation Costs Compared to Dry Storage Costs

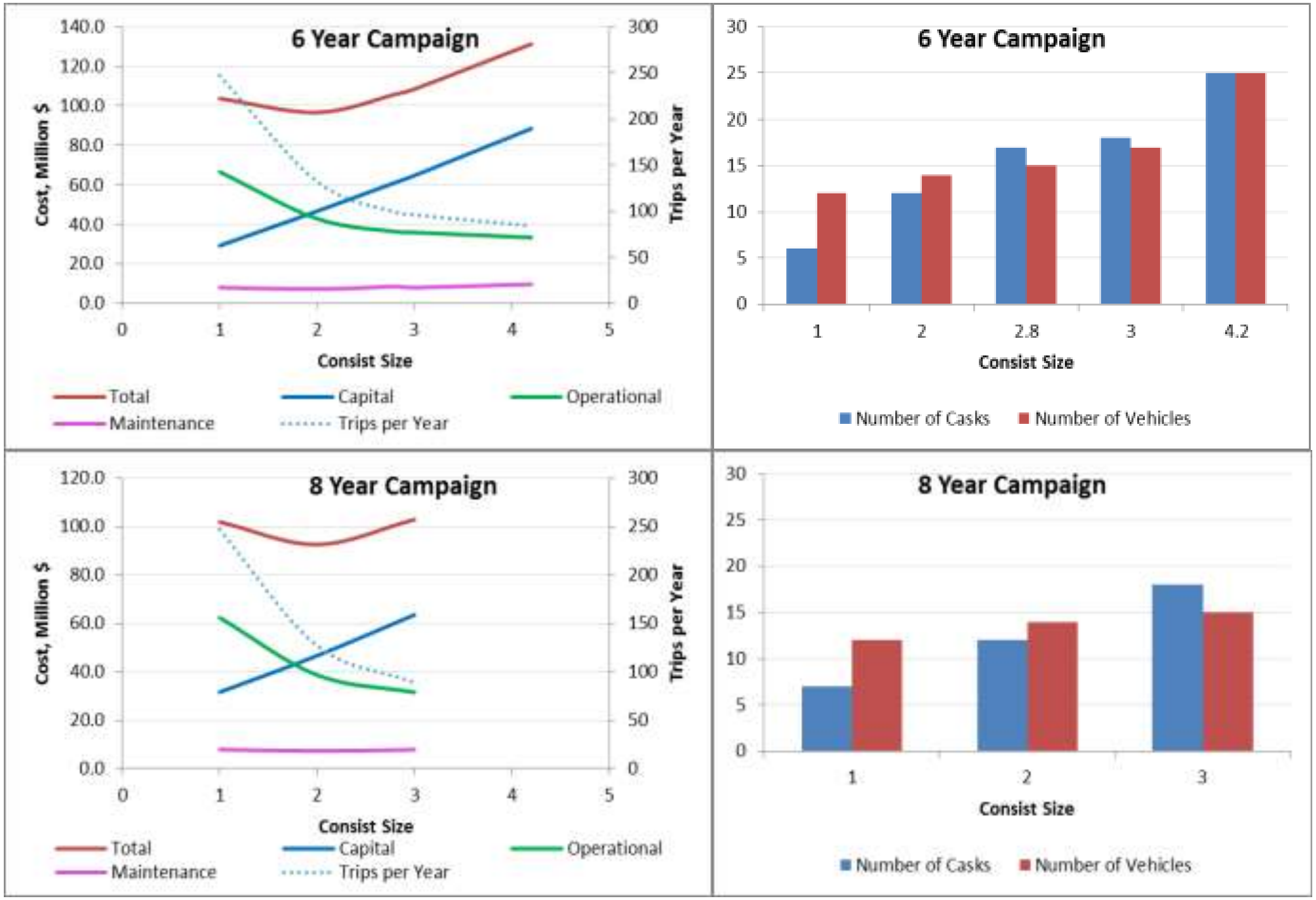
- Dry utility costs are the costs to maintain dry storage facilities at the remaining shutdown sites.
- Dry costs are calculated for the duration of the campaign starting from the first campaign year.
- The annual cost of 6 million dollars per site from the CALVIN database was used.



Unloading of the shutdown sites in 3-5 years is optimal with regard to keeping low transportation costs and dry storage costs.

Consist Size

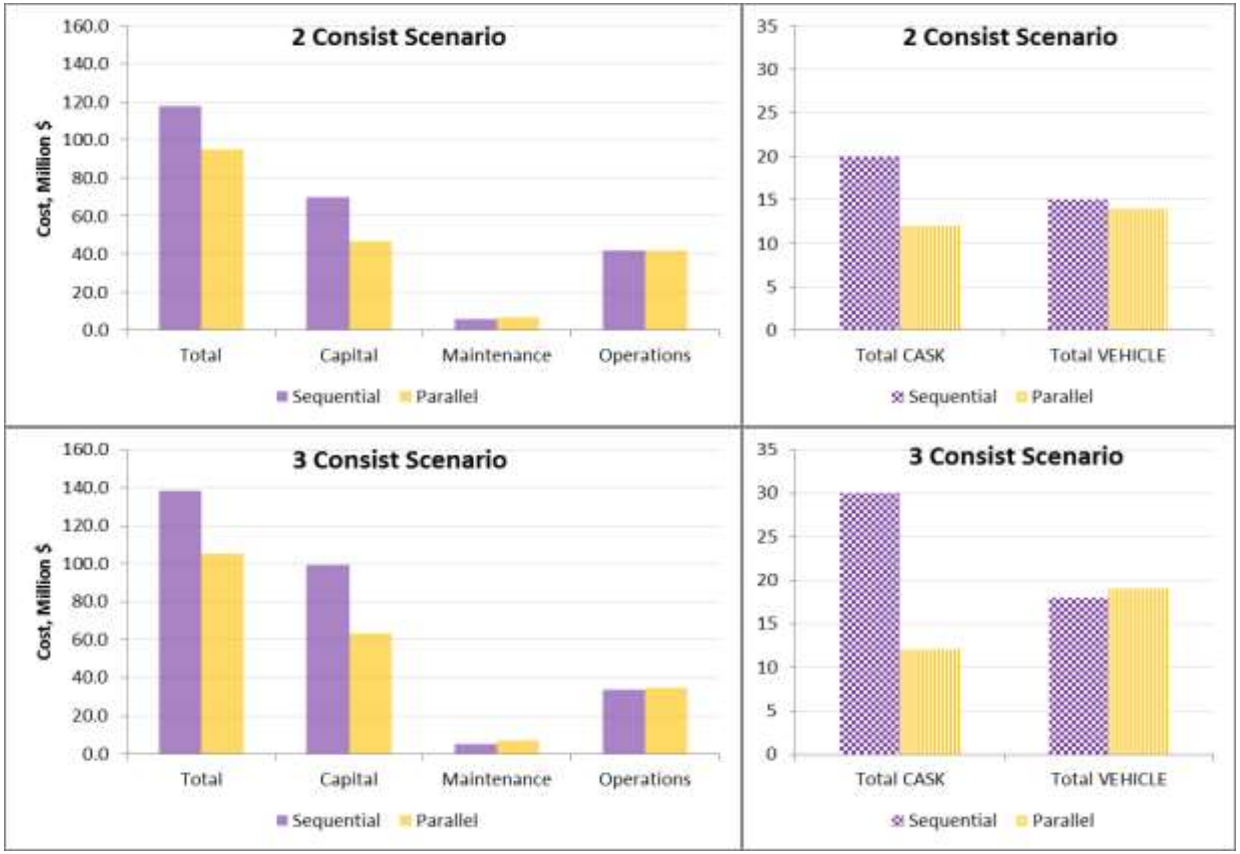
<u>Scenario parameters:</u> parallel schedule, storage in SE USA, co-located maintenance facility.



- ➢ The scenarios with the lowest total cost are the ones with the 2-car consists.
- ➢ The number of trips decreases and the trip cost (mostly mainline rail cost) increases with the consist size.

Sequential versus Parallel Approach

Scenario parameters: 6-year campaign, storage in SE USA, co-located maintenance facility.



- The total cost is significantly higher in the sequential approach because more casks are required.
- The greater the consist size, the larger the impacts of sequential unloading on the total cost

Consolidated Storage and Maintenance Facility Locations

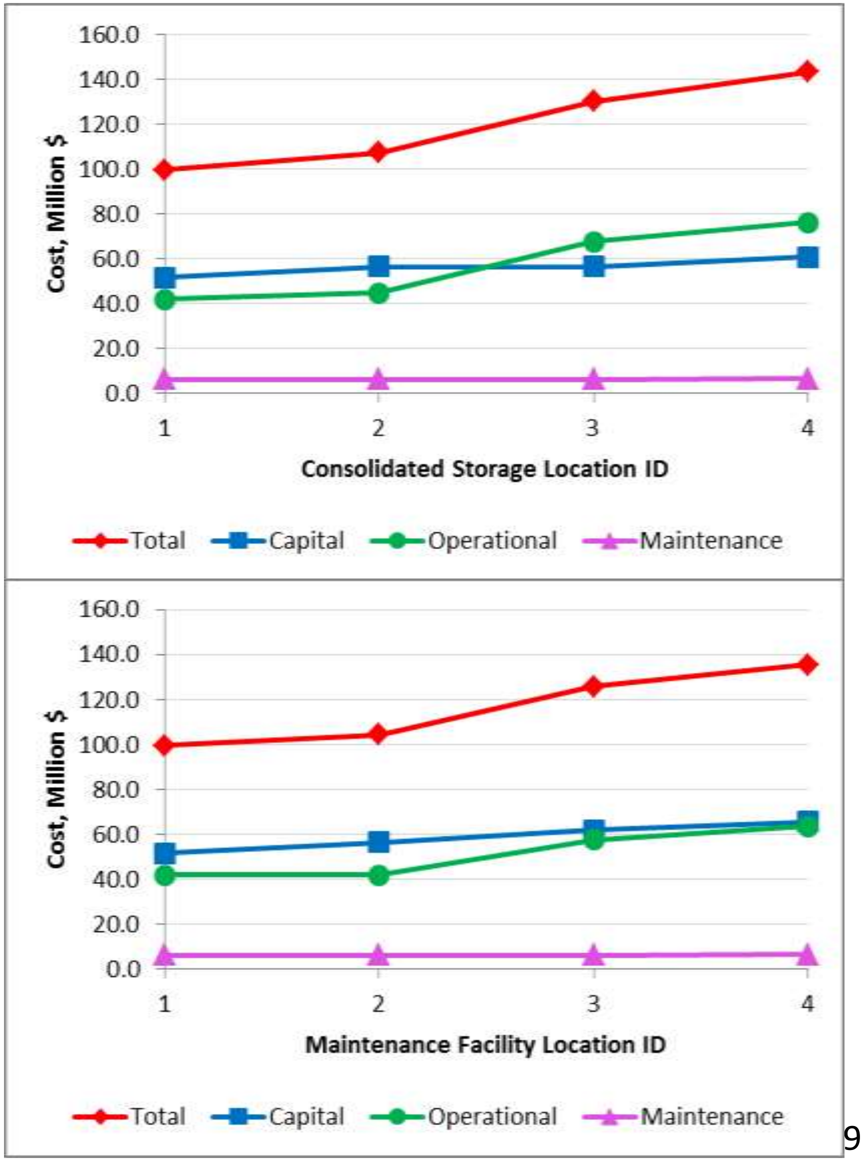
Scenario parameters: 2-car consist size, parallel fuel selection approach, and 4-year campaign.

Consolidated Storage Location:

- The total cost in the case of storage facility in NW location (farther from the majority of the shutdown sites) is 43% higher than in the case of SE location.
- The increase in total cost is due to the increase in operational costs.

Maintenance Facility Location:

- The total cost in the case of maintenance facility (NW location) located away from the storage facility (SE location) is 35% higher than in the case when they are co-located (SE location).
- The increase in total cost is mainly due to the increase in operational costs.

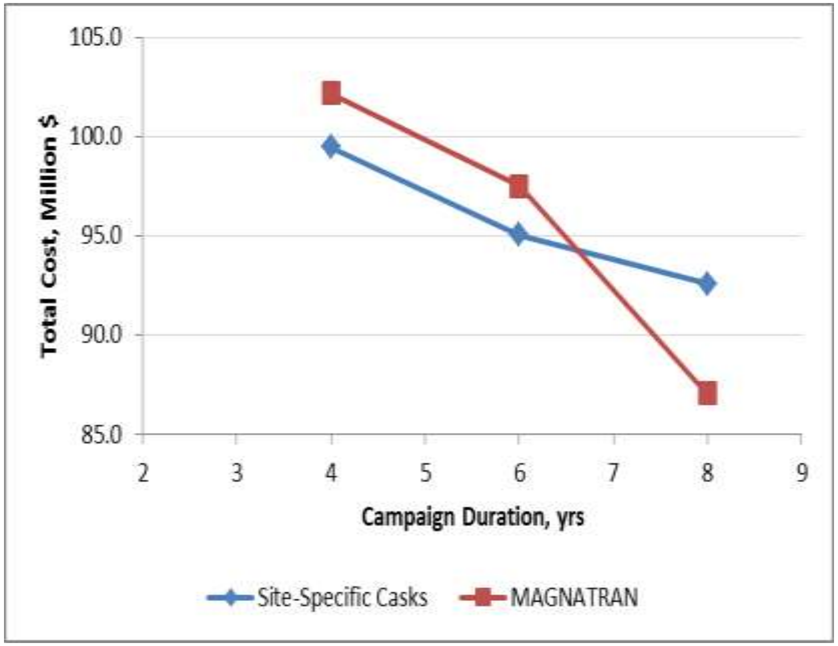


Location ID: 1 –SE, 2 – NE, 3 – SW, 4 -NW

Use of MAGNATRAN Casks

Scenario parameters: parallel approach, 2-car consist size, consolidated storage in SE and co-located maintenance facility.

Site-Specific Casks: site-specific NAC-STC casks were used at Haddam Neck, Yankee Rowe, and La Crosse sites.
MAGNATRAN: NAC-STC casks at Haddam Neck, Yankee Rowe, and La Crosse were replaced with NAC-MAGNATRAN casks.



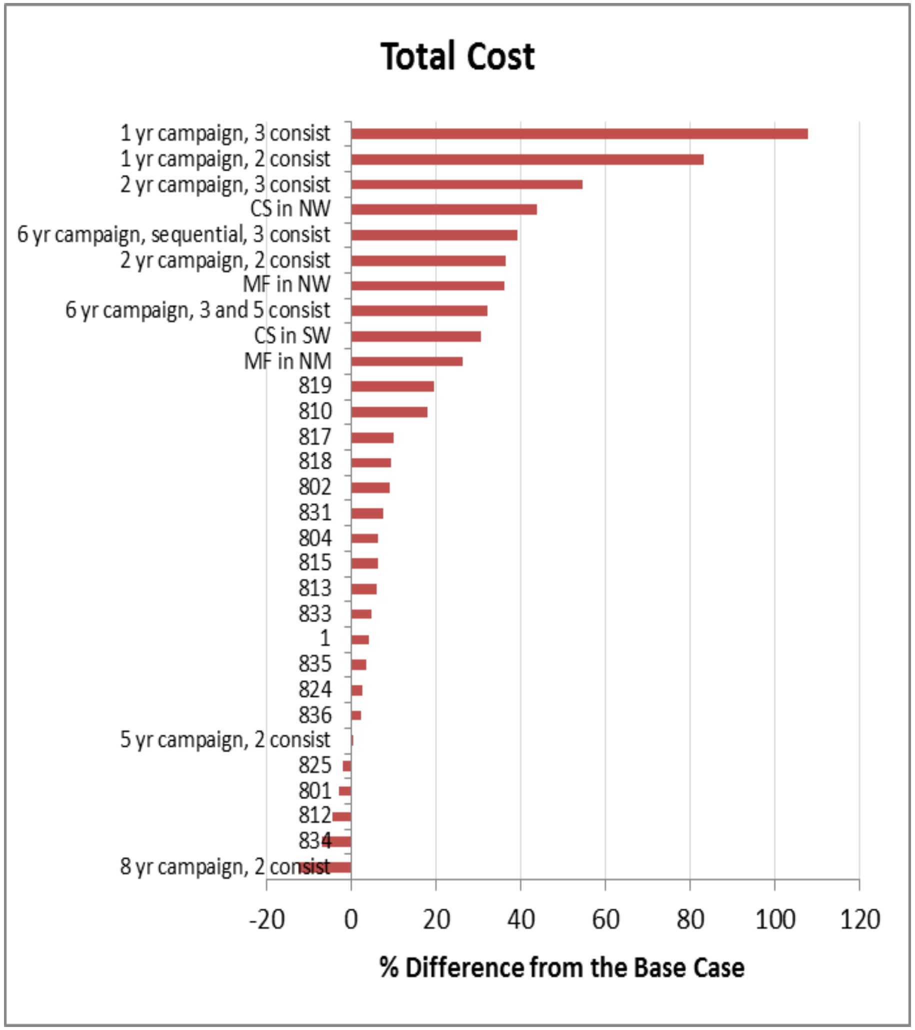
- Using the same cask types (NAC-MAGNATRAN) at multiple sites has benefits only for the long duration (greater than 6 years) campaigns.
- If the campaign is short, using the same cask type results in higher total costs because some of NAC-MAGNATRAN casks are acquired later in the campaign at the higher price.

Scenario Ranking Based on Their Performance

Base Case Scenario: parallel schedule, 4-year campaign, 2-car consist, co-located storage and maintenance facilities in SE.

Capital Costs:
The major factor is the campaign duration. The next two important factors are the fuel selection approach and the consist size.

Operational Costs:
The major factor is the location of the consolidated storage and maintenance facilities. The next important factor is the consist size.



Conclusions

Characteristics of the scenarios with highest transportation costs are:

- Short duration campaign
- Sequential schedule
- Consolidated storage located far from the majority of the shutdown sites (NW or SW)
- Large consist size
- Maintenance facility not co-located with the storage facility.

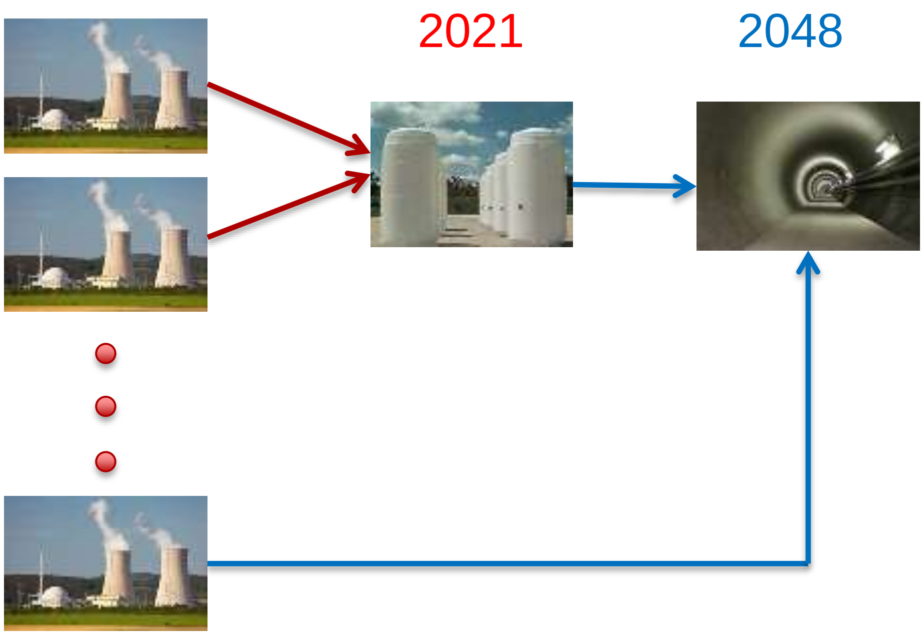
Characteristics of the scenarios with the lowest transportation costs are:

- 4 or 5 year campaign
- Parallel schedule
- Consolidated storage facility close to the majority of the shutdown sites (NE or SE)
- 2-car consist
- Maintenance facility co-located with the storage facility.
- Site-specific transportation casks (the ones currently licensed for each site).

➢ Longer campaigns would be slightly less expensive, but would result in higher dry storage maintenance costs.
➢ The major contributors to the total cost are capital cost and operational cost.
➢ Generally, the factors that minimize capital costs (small consist), maximize the operational costs and vice versa.

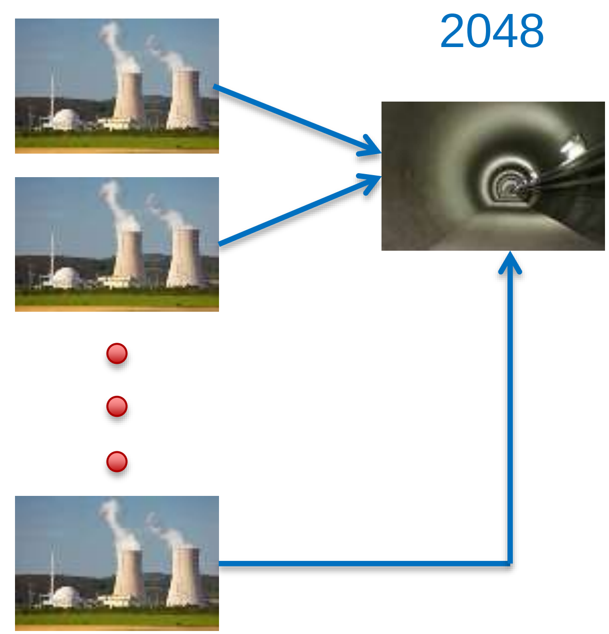
NOTE: These result should be used as a general guidance. There are many specific details not considered in this analysis that may affect the selection of the best strategy in unloading the shutdown sites.

Removing SNF from All the Reactor Sites



ISF Scenarios

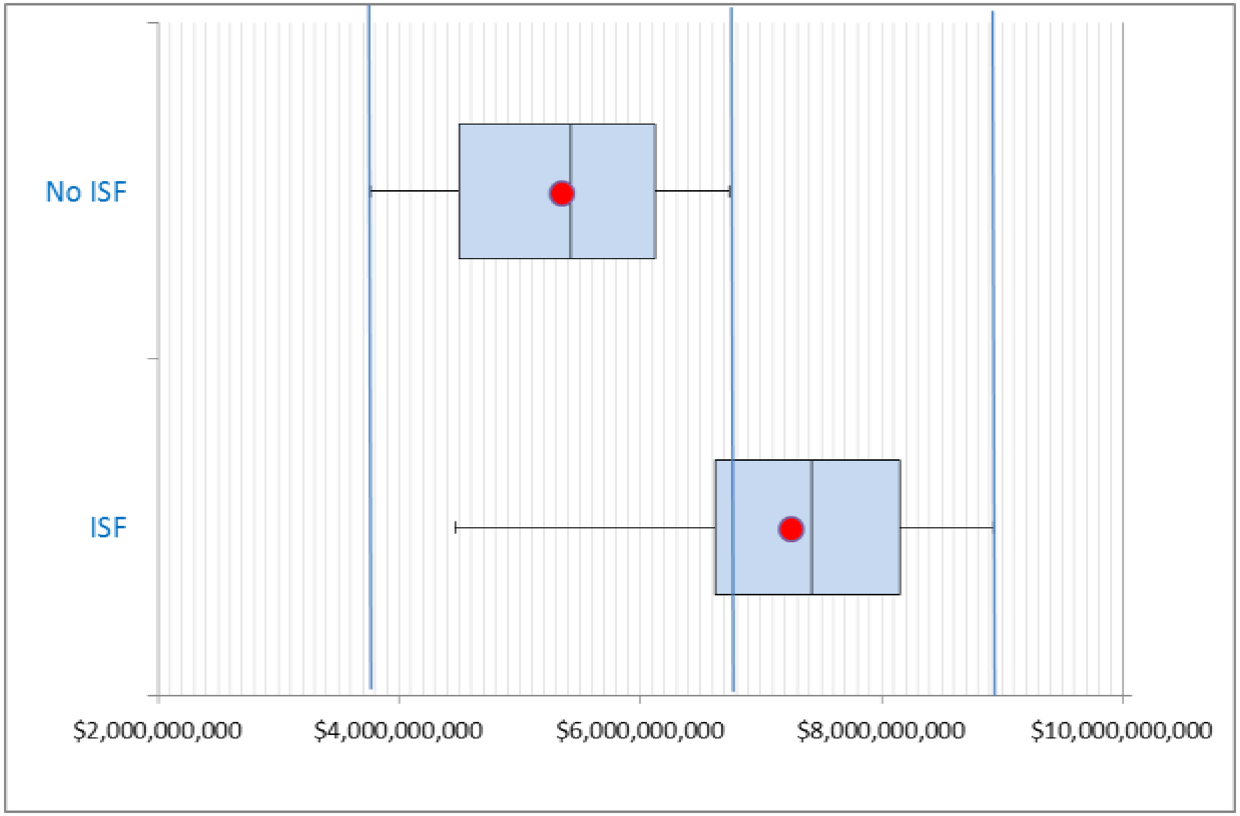
SNF is transported to ISF starting in 2021 and to a repository starting in 2048.



No ISF Scenarios

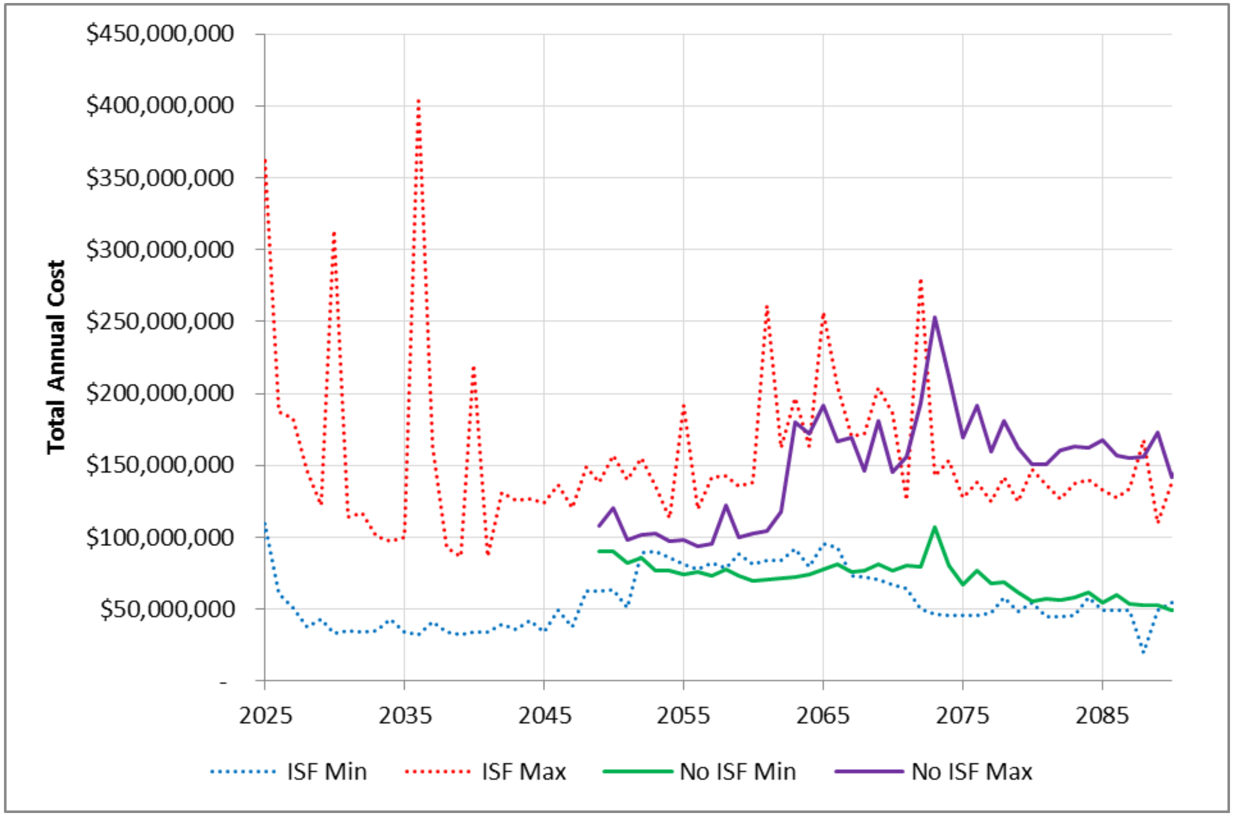
SNF is transported directly to a repository starting in 2048.

Total Transportation Cost



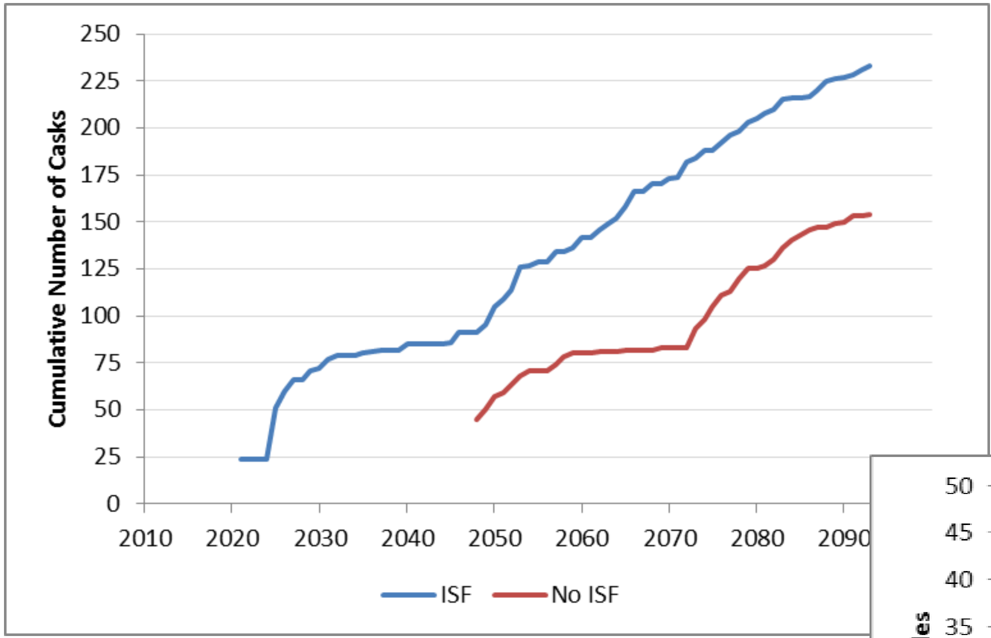
Mean Total Cost: $5.3B (No ISF) and $7.2B (ISF)

Transportation Cost Spending Profiles



The additional costs in scenarios with ISF are related to transportation from the reactor sites to ISF during 2021 to 2048.

Example of Acquisition



Total Casks	Total Vehicles	Total Cost ($B)	Total Miles	Total Trips
233	80	4.3	1.5E7	7228
154	64	5.0	1.2E7	4878